Knowledge mentoring as a framework for designing computer-based agents for supporting musical composition learning

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Knowledge Mentoring as a Framework for Designing Computer-Based Agents for Supporting Musical Composition Learning

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Dedication

This thesis is dedicated to my family. To my wife Terri for all her patience, love and support and to our children Billy and Meghan, both of whom were born while the thesis was in labour! And finally, to my mother and father for their unconditional love over the last 40 years.

EX12

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Abstract

An approach to the design of teaching agents in problem-seeking domains — that is based on a systematic relationship between theoretical framework, analysis of empirical data, computational model and computational implementation — has been developed.

The theoretical framework, called the *Knowledge Mentoring framework* (KMf), was developed to investigate how studies of dialogue and interaction can be exploited in a practical way by designers of computer-based teaching agents. A particular focus was the following musical education problem: when interacting with a computer-based music system, many students do not spontaneously reflect on their activity, they often need to be encouraged to do this. The KMf provides a taxonomy and definitions of the pedagogical goals involved in a 'mentoring' style of teaching. Mentoring is an approach to teaching that aims to support learners' creative, metacognitive and critical thinking, these being essential to musical composition and other open-ended, problem-seeking domains.

This theoretical framework was used to guide the analysis and modelling of data produced by an empirical study of human teacher-learner interactions. Information on the temporal ordering of teacher-learner interactions was revealed (modelled as state transition networks and a mentoring script). Findings from the analysis also included a pause taxonomy (that provided evidence of a link between pause length and learner ability) and the occurrence of reciprocal modelling (where participants in learning interactions built up models of the other participants' expectations).

The theoretical framework and the analysis findings were then used to develop a computational model for teaching agents in problem-seeking domains. Aspects of our theory, analysis findings and computational model were incorporated into a computational implementation: a pre-prototype teaching agent called MetaMuse. A Cooperative Evaluation of MetaMuse with teacher-composers showed that it had the potential to promote creative reflection in learners.

Chapter 1 - Introduction

A pervasive problem in musical composition education is that there is no "correct" body of knowledge to teach. In musical composition it is not just a question of solving a problem, it is more a question of *seeking* out the nature of the problem and then devising an approach to solving it. This gives rise to the requirement for some form of open dialogue between teacher and student. However, although dialogue is important in promoting learning, especially in problem-seeking domains, we do not have available to us the precise details of the mechanisms of interactive learning in these domains. This problem is made more acute by the use of musical software. Evidence supports the view that the use of sequencer software in the current training of composers in higher-education appears to limit higher-order thinking in some learners.

One approach to building computer-based systems to address the above problems is to base system design on the study of human teacher-learner dialogue and interaction. System design based on such an approach requires an appropriate teacher-learner interaction analysis technique that includes the participants' goals and creative intentions. However, existing research does not provide such a technique. This thesis presents an approach to the design of teaching agents in problem-seeking domains that aims to address the problems outlined above. Our design approach is based on a systematic relationship between theoretical framework (called the Knowledge Mentoring framework), analysis of empirical data, computational model and computational implementation.

Section 1.1 below provides an overview of the arguments, claims and contributions that are made in this thesis with respect to the role of dialogue in computer-based musical learning and observations of learning. In Section 1.2 we present an overview of our systematic, computer-based teaching agent design approach. Section 1.3 then briefly presents some evidence, from the literature, to support the claims made in the argument presented in Section 1.1 (further evidence will be presented throughout the course of this thesis). This is followed by an illustrative example of a Knowledge Mentoring interaction (Section 1.4), a description of the evolution of the thesis (Section 1.5), and an overview of the structure of this thesis (Section 1.6)[1].

1.1. The role of dialogue in computer-based musical learning and observing learning

Dialogue between teachers and students may be important in promoting learning (e.g. Vygotsky, 1978; Leontiev, 1975; Lipman, 1991; Jones and Mercer, 1993; Pilkington and Mallen, 1996). Students who are placed in a "learning environment" will usually need to interact with a teacher or learning facilitator at some point, in order to receive guidance (Elsom-Cook, 1990), feedback and explanations (Laurillard, 1993). The adaptive role of a teacher is of central importance to learning (Laurillard, 1993) because learning resources and media (such as books, journals, CD-ROMS, online databases or World Wide Web resources, etc.) are rarely able to adapt to a particular group or individual's learning requirement. Students bring different histories of learning with them to a particular situation and therefore have different learning needs (Laurillard, 1993; Ramsden, 1992). As a result, when a student interacts with the various learning resources that are available in the learning environment, questions that require clarification may arise. Such learning resources rarely contain within themselves the explicit guidance that would make it clear as to how they should be understood. Furthermore, these resources and media, typically, do not provide guidance on how they should be used together in a coherent fashion so that learning can occur. For example, the tutor may be required to mediate between the learner and their understanding of the way in which they should use learning resources in order to meet the assessed learning outcomes of a particular programme of study. Consequently, in a learning environment we get a complex set

[1] A glossary has been provided on page 257 in an attempt to assist reader understanding of some of the multidisciplinary terms used in this thesis.

of relationships between how a learner thinks (cognition), how the learner interacts with teachers and peers, and the various media and resources that are available to support learning. The institution and society in which the learning takes place will also exert an influence on learning in more subtle ways.

The teacher is often more than a source of information. As was pointed out above, the teacher plays a key role in mediating a student's learning, acting as a kind of "go-between" or guide for the learner as they engage with the various elements of the learning environment, i.e. as they engage with other learners and tutors, learning resources and media, programme learning outcomes and assessment methods (Laurillard, 1993; Knight, 1995). The teacher can also help the learner to become more autonomous, to learn how to learn, to reflect on his or her own problem-solving. The way that such explanation and guidance is provided by a teacher is usually through dialogue (either face-to-face, written or virtual), since this enables the teacher's help to be adapted and individualised to a particular student's needs. Dialogue also enables the student to verbalise and articulate his or her needs and understanding. This latter process of making knowledge explicit, and reflecting on it, may itself be an interactive learning mechanism (e.g. Chi, Bassok et al., 1989). Providing computer-based learning support that is able to acquire aspects of the role of 'teacher as mediator' is a growing area of research and development (as our literature review below will show). However, in this thesis what we are claiming is that we do not have available to us the details of the mechanisms of interactive learning that are precise enough to inform the implementation of computer models of teachers in open-ended, problem-seeking, creative domains such as musical composition (the domain studied in this thesis).

Some computational mechanisms of learning have been described in the literature, but usually for closed procedural domains like maths and physics (e.g. Anderson and Boyle, 1985; VanLehn and Jones, 1993), that do not involve creativity as part of the learning process (although, of course, computer programming is also a design task). Furthermore, although there are many references in the literature on interactive learning mechanisms as they relate to computer-based learning (e.g. van Joolingan and de Jong, 1991; Baker, 1994; Baker and Bielaczyc, 1995), we still do not have sufficient detailed knowledge concerning dialogues in open-ended domains that extend over a full tutorial[2]. We do not, therefore, have a specifically adapted body of research to draw upon in the designing of computer-based systems for supporting learning from dialogue in open-ended, creative domains.

In this thesis we propose a solution to the problem described above for the specific domain of musical composition. **This solution proposes a systematic system design method called Knowledge Mentoring.** This design method includes a goal-based approach to supporting learning in open-ended domains called 'mentoring'. Mentoring is an approach to tutoring interactions that supports learner creative, metacognitive and critical thinking, these being essential to musical composition and other open-ended, problem-seeking domains.

1.1.1 Dialogue in problem-seeking domains

The need for dialogue is especially relevant in open-ended, problem-seeking domains[3] such as musical composition learning. But why should this be the case?

Given the open-endedness in music, both in the sense of the problems that could be addressed, and in the sense of the space of possible 'solutions', any educational intervention must be similarly open. A teacher can not simply be directive and "transfer" knowledge because in problem-seeking domains, there is no "correct" body of knowledge. Teaching interventions can not be restricted to the giving of feedback on simple correct or incorrect response. Like knowledge in the humanities (Goodyear and Stone, 1992), for example, in the domain of musical composition knowledge is essentially problematic: it is not just a question of solving a problem, it is more a question of *seeking out the nature of the problem* and then devising an approach to solving it. Thus, *problem-seeking domains* usually require some form of open dialogue between teacher and student. This shifts the emphasis away from the

[2]Typically, dialogue analysis is undertaken for only short samples of dialogue (usually less than two minutes), and ordinarily at a low level of analysis, e.g. turn-taking.

[3]The notion of problem-seeking was first proposed in the context of AI-ED by Cook at a Music Education workshop, held as part of AI-ED 93, Edinburgh. An extended version of this paper appears as a book chapter: Cook, 1994a.

assertion of facts and towards interactions that encourage the types of creative, metacognitive and critical thinking and interactions that will be explored in this thesis[4].

This thesis will introduce a definition of metacognitive processes that is relevant to problem-seeking and will describe how a specific approach to interactions, called mentoring, can be used to promote higher-order thinking in learners.

1.1.2 Design approaches for artificial teaching agents

The main motivation of this thesis is to understand how computer-based teaching agents[5] can engage in educationally beneficial *dialogues* with learners, in *problem-seeking domains.* However, it is not immediately obvious as to how one should go about designing artificial teaching agents that are capable of engaging learners in such problem-seeking interactions. There appear to be two main possible approaches to solving this problem. One approach that has been adopted by several researchers in Artificial Intelligence in Education (AI-ED), e.g. (del Soldato, 1994; Lester, Converse et al., 1997), is to implement a system, using existing theory, whose pedagogical decisions are based, at least initially, on the designers' intuitions. The system can then be refined on the basis of analysing and evaluating its interactions with student users. The second possibility — the one followed in the research described in this thesis — is to base system design on theory and the empirical study of dialogues between human teachers and students, in the problem domain. In this case, the system can also then be refined on the basis of evaluation of its interactions with users (i.e. students).

Why choose the second approach presented above? Our motivation for adopting this second approach is, quite simply, that since human expertise does exist (i.e. teachers) in many domains, including teaching musical composition, then why should system design not benefit from this, instead of beginning from almost zero expertise? Of course, no single group of human teachers are able in practice to

[4]Section 1.3 explores this point in greater detail.
[5]Agents can be human or computer-based.

produce all of the space of possible teaching interventions, experts do not all necessarily agree, and their pedagogical decisions are not always optimal. It is not a question of direct transfer of expertise from human to machine, but rather to use human expertise, when *transposed* (rather than *transferred*) to the computational medium, as an appropriate starting point for system design, which can then be refined on the basis of evaluation with users. This user-centred, iterative approach to system design is discussed in Chapter 4.

It is possible to object to our chosen line of inquiry (i.e. approach to system design) on a number of theoretical grounds. We shall now discuss three possible grounds for objection. The first possible objection would be on the basis that the organisation of human-human communicative interactions (the chosen subject for study in this thesis) may not be an appropriate approach for organising what will be the mainly textual interactions between computer and human. The second possible objection would be to cast doubt on the use of dialogue data as an indicator of the beliefs of participants in a dialogue, i.e. coding and analysing verbal dialogues may fail to take into account either the participants' intentions or the (personal) meaning system of which they may be a part. The third possible objection revolves around the issue of whether it is in principle appropriate to apply *descriptive* frameworks (like the typical mentoring networks and the script identified as results in Chapter 5 of this thesis) in a *prescriptive* way to guide system design. Below we now address each potential objection in turn.

We would make two points with respect to the first possible objection (i.e. human-human to human-machine dialogues). The first point is that relatively little research has been carried out on the nature of educational dialogues in problem-seeking domains; consequently these domains have been little formalised. It is therefore a reasonable approach to begin from the very rich body of information that can be gleaned from the study of human expertise in face-to-face dialogues. In other words, few strong domain theories exist that would enable us to have intelligent or informed intuitions in these types of domains. With respect to the first possible objection we also note the following second point. As we will argue below, no systematic theory of human-computer learning interactions has delivered the insights or framework that we require to design a computer-based teaching agent in open-ended domains. It is therefore a reasonable starting point to model human-computer interactions on human-human interactions.

The second possible objection (i.e. the gap between dialogue and beliefs) can be addressed by the use of theory to incorporate, amongst other things, the goals of the speaker (Draper and Anderson, 1991, p. 105). The theoretical framework described below in fact takes this approach. Furthermore, the use of structured interviewing, in conjunction with an analysis of the dialogue data, can help uncover the goals of the dialogue participants (this approach was used in the empirical study described in Chapter 5 of this thesis). However, it should be noted that, with respect to the second objection, this thesis is not proposing a psychological theory of learning. Rather, this thesis addresses the issue of using relevant theory, dialogue data, plus interview data to provide a framework for assisting in the development of computer-based teaching agent design.

The third possible objection is related to the distinction in the AI literature between descriptive and prescriptive models (especially for decision making). Slade (1994) has pointed out that

> "there is a basic dichotomy in the decision-making literature between prescriptive and descriptive models. Prescriptive or normative models focus on how people *should* make decisions, while descriptive theories explore how people *do* make decisions ... descriptive theories can be viewed as bottom-up models, in which the data define the significant features and dimensions of the model. The resulting theory is derived to match the data." (Slade, 1994, p. 194)

Prescriptive methods of decision analysis are mathematically precise and often have as a requirement a method of estimating probabilities and payoffs of outcomes. However, many aspects of learning and teaching lack principled ways of making these mathematically precise decisions. Descriptive models of decision making recognise that an agent does not optimise, but rather 'satisfices' (i.e. the teaching agent selects goals that are good enough) by examining the 'likelihood' of an outcome being achieved. The position taken in this thesis is that goal-based models of decision making in teaching agents must move beyond a strict adherence to mathematical formulations of decision analysis. However, each approach to decision making can gain from the lessons learned from the other approach. The approach taken in our thesis has been one of starting with a descriptive model and to then move towards a prescriptive model.

In order to design artificial teaching agents, on the basis of the study of human teacher-learner dialogues, an appropriate set of techniques is required (i.e. a framework is required) for analysing those dialogues, in a way that can be transposed to system design. However, as we argue here, such techniques do not already exist in the literature. Such work does not exist in linguistics, this discipline is solving different research problems.

The literature on conversation and discourse analysis in linguistics and related disciplines abounds with different analysis techniques. However, each of these techniques were devised to answer specific research problems, and are not directly relevant for designing teaching agents. For example, one concern of psycholinguistics (described by Levinson, 1983, p. 375) is language acquisition in the context of developmental psychology. For it to contribute to a framework for designing computer-based teaching agents, this work on language acquisition would need to include details of how to move from theory and empirical work to a computational model, which it does not. Although some linguists have worked with computer scientists to develop computational theories[6], no computer-based teaching agents appear to have been developed. Similarly, some research from linguistics (specifically a related field called sociolinguistics) has been applied to the design of knowledge based systems[7]; however, this work has not been used to produce a computer-based teaching agent.

In computer-based learning there is very little work that is based on dialogue

[6]E.g. Pierrehumbert and Hirschberg (1990) have worked on models of the meaning of intonational contours in discourse.
[7]E.g. Frohlich and Luff (1990) used conversational analysis theories as the basis for the development of an advisory system for welfare rights.

analysis. The work that has been done tends to examine students' interactions with existing computer-based systems (e.g. Pask, 1976; Recker, 1994; Pilkington and Parker-Jones, 1996). Laurillard (1993, p. 102) has, however, proposed a template for conversations that aims to map out (at a very high level) the steps that are required for the design of interactive and adaptive media. Furthermore, Hartley (1998) has pointed out that although the applications of technology in education are becoming more numerous, they tend to be "disparate, pragmatically oriented, and largely descriptive in the accounts they present" (Hartley, 1998, p. 20), and that we still need systematic development frameworks that are able to "link theories to methodologies and practice" (Hartley, 1998, p. 36).

In AI-ED research, some systems have been developed on the basis of a study of dialogues, but, the relationship between the dialogue data and the system is usually non-systematic (e.g. Stevens, Collins et al., 1982; we elaborate on this point in Section 1.3.4), or was not used to develop a teaching agent[8]. Furthermore, educational research on interactions has tended to focus on a level of analysis and description that is of limited value for the types of models and theories that we wish to construct in AI-ED (Elsom-Cook, 1991, pp. 76-77).

1.1.3 Summary of thesis research question, claim and argument

The *main agent design research question* to be addressed in this thesis (which is an elaboration of the 'main motivation' of the thesis, described above) can be stated as follows: how, or to what extent, can studies of dialogue and interaction be exploited in a concrete way by designers of teaching agents in open-ended problem-seeking domains? The term "interaction analysis" is used in this thesis, rather than the more common "dialogue analysis", because "interaction" includes linguistic communication (i.e. speech) and non-linguistic forms of communication (e.g. musical actions that have communicative intent or actions like pointing at the computer screen). In summary, we argue as follows:

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[8]Winkels (1992) used dialogue analysis to develop a help system; Baker and Bielaczyc (1995) used dialogue analysis to develop guidelines for developers of Computer Supported Collaborative Learning environments.

- Although dialogue is important in promoting learning, especially in problem-seeking domains, we do not have available to us the precise details of the mechanisms of interactive learning in these domains.
- This problem (noted in bullet point 1) also arises for the case of human-computer educational dialogues, yet here we have the added problem that we need to know how to design teaching agents that are capable of sustaining such dialogues.
- Two possible approaches to designing computer-based teaching agents are "theory-intuition to design-evaluate-and-refine", and from "human-teacher-student-dialogues and theory to design-evaluate-and-refine". We choose the second approach, because, given that problem-seeking domains have not yet been adequately formalised, our intuitions can not be sufficiently informed. It is therefore reasonable to begin from what human experts do, to transpose this knowledge to system design and refine the system on the basis of evaluation.
- System design based on the study of human behaviour requires an appropriate teacher-learner interaction analysis technique that will include the participants' goals and intentions, but existing research does not provide this.

As we explain in Chapter 3, the KMf extends Self's (1993) DORMORBILE architecture in that we propose that there are a set of goals that have 'implicit intentions' that will vary in their purpose, depending on the level in the learner being targeted (i.e. the monitoring or reflection levels). Furthermore, reflective thinking (a level in Self's framework) may involve 'going-beyond' type thinking and hence tends to overlap with what are called in this thesis 'creative thinking goals'. The agent work described in Chapter 6 of this thesis extends some aspects of Blandford's (1991) work on agents. Specifically, we extend Blandford's work by applying it to the creative domain of musical composition and by using empirically derived state transition networks as the basis for planning (Blandford's agent does not perform any planning). The implemented teaching agent, called MetaMuse, differs from other Intelligent Tutoring Systems' dialogue models in that no other systems have been reported for promoting creative reflection about musical composition in higher-education. Furthermore, no teaching agent has been described in the literature that is based on a systematic relationship between analysed interaction data and implemented agent.

In summary, the main contribution of this thesis is an original, user-centred framework that provides an iterative approach to designing computer-based teaching agents in problem-seeking domains that is based on a principled and systematic relationship between theory, empirical data, computational model and computational implementation. **By a systematic "approach to designing computer-based teaching agents" we mean a specific set of coherent relations between a theoretical framework [TF], an analysis technique [AT], a computational model [CM] and a computational implementation [CI].**

1.2 Systematic approach to designing computer-based teaching agents

This thesis proposes a *theoretical framework* for knowledge mentoring (Chapter 3), application of the theory to the *analysis* of dialogue data (Chapter 5), a *computational model* that is coherent with the theory (Section 6.2), and application of the computational model to a *computer implementation* (Section 6.3.). Thus our approach to designing computer-based teaching agents has four components:

1. *Theoretical framework* [TF] of knowledge mentoring, the KMf, which includes the following sub-components:
- categories of goals drawn from theory,
- a three level framework of goals, subgoals and communicative acts,
- a theoretical model of teaching agents (values, wants, commitment, intention and an action cycle).

2. *Analysis techniques* [AT] of interaction data. The categories and the three

level framework from component 1 are used to guide the analysis of empirical data and to thus generate results.

3. *Computational model* [CM], i.e. system design.

4. *Computer implementation* [CI], i.e. MetaMuse (operating within the framework of the Coleridge computer-based environment for musical composition).

Sections 1.2.1 to 1.2.4 briefly introduce the four components of our approach to designing computer-based teaching agents. Section 1.2.5 elaborates on the nature of the different systematic links between [TF], [AT], [CM] and [CI].

1.2.1 Theoretical framework [TF]: Knowledge Mentoring framework

We mentioned above that dialogue was particularly needed in problem-seeking domains like musical composition. The question therefore arises as to precisely what type of dialogue is appropriate for teaching in these types of domains? The answer to this question, proposed here, constitutes the *principal theoretical contribution of this thesis.*

The Knowledge Mentoring framework or KMf provides a taxonomy and definitions of the pedagogical goals involved in a mentoring style of teaching and a convenient tool for the analysis of protocol data in terms of communicative acts (Baker, 1994) and associated goals. The KMf provides teacher and learner goal trees that contain goals and sub-goals at the top two levels and an utterance level (of communicative acts) at the bottom level. The KMf proposes an explicit relationship between goals and communicative actions in purposeful dialogues. By drawing on work by Power (1979) the KMf uses the idea of a shared goal tree, where the responsibility for various nodes is either shared or distributed between two agents engaging in interactions relating to a problem-seeking task (only teacher-learner pairs were observed in our study).

In the theoretical model of the teaching agent, an action cycle is used to determine what action the teaching agent is to take at each time increment of the current situation. When it is the teaching agent's turn, it generates a list of sub-goals *(wants)* that are available to it at the current node in a network (networks are empirically derived).

The theory [TF] has links with the empirical data in that the empirical analysis [AT] described in our thesis clarified which goals each agent (teacher or learner) used when interacting with one another. Thus, in our theoretical framework some goals belong exclusively to one type of agent (e.g. to the teacher) whereas other goals are shared between agents (teacher and learner). Furthermore, the theory has links with the computational model [CM] in that the KMf taxonomy was used to structure the computational architecture of our teaching agent. Also, the KMf definitions of the pedagogical goals, sub-goals and communicative acts were used to guide the nature of reasoning or interactions that were instantiated in the implemented computer-based teaching agent [CI].

1.2.2 Analysis techniques [AT]: empirical data and results

The empirical study investigated the way in which a human teacher supported *higher-order, musical thinking in learners.* Four sessions were involved in the study. In each session a teacher and one student interacted with each other and a computer-based learning environment. The KMf [TF] described above was used to interpret experimental data. By using the KMf, the interaction analysis involved a categorisation of the study data (transcriptions of the sessions) into goals and communicative acts. Frequency counts were generated for each category. Further analyses of this categorised data generated various results. In total, seven detailed interaction analyses techniques [AT] were used to analyse the data. The fourth analysis approach, for example, included the use of post-experimental interviews (i.e. interviews based on observed events in the interactions) in order to elicit the intentions and goals of subjects.

The interaction analyses produced some general findings and four main results.

The four main results were:

(Result 1) a pause taxonomy,

(Result 2) the existence of reciprocal modelling,

(Result 3) seven distinct mentoring stages (with associated state transition networks), and

(Result 4) a script of the most frequent mentoring interactions.

Thus, the theoretical framework [TF] gave rise to analysis categories in terms of goals, and communicative acts which were interpreted as a means of achieving the goals. Furthermore, the systematic analysis [AT] of the data went further than proving the adequacy of the theoretical framework; it generated several new results which, we propose, would be useful in the design of a teaching agent [CM] in either a user model, an instructional planning component or in a decision model for interaction. In this sense the theoretical framework can be said to be systematic (i.e. there is a strong link between theory and results brought forth by the analysis technique).

1.2.3 Computational model [CM]

In the computational model of the teaching agent, an action cycle is used to determine what communicative actions to make at each time increment of a session. When it is the teaching agent's turn, it generates a list of wants that are available to it at the current node of a network. The agent then uses a preference mechanism to select the 'want' that best meets its current situation (i.e. the agent tries to become 'committed' to one sub-goal). Appropriateness conditions are used to define the conditions under which a sub-goal can satisfy a pedagogical goal. Furthermore, the degree to which each sub-goal or action meets the agent's values is specified by (empirically derived) preference weightings. Once committed to a particular sub-goal, the agent forms an 'intention' to take action. Before eventually making a communicative act, the agent may use a 'move function' to perform some local adaptation of its utterance.

Aspects of our theoretical framework [TF], i.e. the theoretical model of teaching agents (values, wants, commitment, intention and an action cycle) are represented in our computational model [CM].

1.2.4 Computational implementation [CI]: MetaMuse

A prototype teaching agent was implemented [CI] and evaluated that utilises some of the results from our empirical study (i.e. the state transition networks and the data used to build the mentoring script). The characteristics of the teaching agent are that it can engage in 'principled' interaction to promote learner creative reflection but that it has very limited, fixed expertise in the domain of musical composition (it does not learn about the domain). The interactions that the teaching agent engages in are described as principled because they are based on an analysis of human interactions (i.e. the work summarised above and presented in Chapter 5). Thus, the prototype teaching agent has strong links to the theoretical framework (the three levels and motivating agent theory) and the analysis data (the approaches to planning and decision making that were implemented in the teaching agent drew upon empirical work).

The prototype teaching agent was evaluated in the domain of musical composition in order to validate its utility. The formative evaluation of the teaching agent (which is called MetaMuse) with teacher-composers showed that it had the potential to be able to promote creative reflection in learners when used in the classroom with undergraduate composers. This finding provides support for the user-centred, systematic design approach claim being made in this thesis.

1.2.5 Other systematic links between: [TF], [AT], [CM] and [CI]

In the above description of our design approach we have highlighted that a systematic relationship between the four design components exists. We also highlighted examples of the systematic link between [TF], [AT], [CM] and [CI]. Other links are discussed below.

Aspects of both [TF] and [CM] have strong links with the empirical data obtained by the [AT]. For example, they both require empirically derived state transition networks for planning. The interaction analysis [AT] in turn allows the computational model [CM] to be instantiated in a specific case [CI], i.e. mentoring creative reflection in musical composition. Furthermore, the evaluation of the computer implementation [CI] also provided indications as to how the computational model could be extended. Since the computer implementation was designed to demonstrate the feasibility of the wider computational model, and to allow a formative evaluation, it did not therefore incorporate all aspects of the wider computational model. We describe logical and feasible extensions to the computer implementation to incorporate other aspects of the computational model in the conclusion (Chapter 7).

1.3 Research background to the thesis

This section provides further evidence to support the claims made in the arguments presented above.

1.3.1 How and why does one learn from dialogue?

Constructivism (described by Wasson, 1996) sees the major goal of education as the creation of rich sets of cognitive tools to help learners explore and interact with their environment and is closely associated with Piaget's genetic epistemology theory of cognitive development (see, Kearsley, 1994, for a description). Cognitive tools are generalisable tools used to engage learners in meaningful cognitive processing; knowledge construction and facilitation (internal and external). For example, computer-based cognitive tools are in effect cognitive amplification tools that are part of the environment. Environments that employ cognitive tools are described as distributing cognition; they are constructivist because they actively engage learners in the creation of knowledge that reflects their comprehension and conception of the information rather than focusing on the presentation of objective knowledge. It is this last item that contrasts with the behavioural approach (see, Hartley, 1998, for a description) which would focus on content selection, sequencing, structuring and presentation.

Jones and Mercer (1993) argue that a theory of learning (i.e. behaviourism or constructivism) is not the best framework for analysing what goes on in understanding the use of media like computers in education, rather a theory and analysis of teaching-and-learning is needed. The KMf, described above, takes a similar approach, drawing as it does on theory and analysis of teaching and learning. Jones and Mercer like the approaches to understanding teaching and learning that have been based on Vygotsky's *cultural-historical theory* of human activity. For Vygotsky (1978), human mental functions appear first as inter-individual and then intra-individual, that is, by the use of socially developed tools, both technological and psychological ones. For Vygotsky, however, the unit of analysis was still the mediated action of an individual and how that individual developed. Vygotsky also put forward the concept of the zone of proximal development (ZPD), which is the difference between a learner's real level of development and their potential level of development.

Leontiev (1975) expanded Vygotsky's cultural-historical theory to an *activity theory* approach to human interaction where reality consists of mediated, social, hierarchically organised, developing, internal and external, object-oriented activities. For Leontiev the unit of analysis was extended to include the collective activity, something done by the community with a motive (which need not be consciously recognised), but composed of individual actions which were directed towards a goal. The individual's mediated actions could still be analysed, but there was now a social dimension (being part of a collective activity) which could be used to understand the individual's actions.

Recent research suggests that teachers can not reliably expect to cause learning (Draper, 1994). Other work with computer-based simulations (Twigger, Byard et al., 1991; van Joolingan and de Jong, 1991), which are used to help students acquire explanatory accounts of the real world, shows that students may fail to generate deep causal models of the behaviour under simulation because they concentrate on manipulating the simulation objects. With respect to the previously stated finding, Pilkington and Mallen (1996) make a strong case for a more Vygotskian (1978) perspective in interaction, i.e. where the teacher mediates knowledge about the society and culture so that it can be internalised by the learner. In such an approach, interaction is seen as an important component of the learning environment, helping students to recognise and resolve inconsistency. These researchers also point out that:

> "... if we are to improve the quality of the interaction, then we need to understand the mechanisms by which dialogues work ... We need to know how and why, some kinds of dialogue ... seem able to trigger reflective engagement and conceptual change." (Pilkington and Mallen, 1996, p. 213-4)

The idea that dialogue can help to promote learning is not new; for example, in the Meno dialogue Socrates (Plato, 1924) used repeated questioning to get a slave boy to discover for himself that the area of a square can be doubled by multiplying each side by $\sqrt{2}$. Recently, some researchers have suggested that dialogue with a teacher may be required if the goal is to promote reflection and conceptual change:

> "... self-reflection, or even reflective discussion between students may not be effective in changing beliefs and their 'organisation' into conception. This requires dialogue with a teacher. But ... can a computer system be improved/designed to assist the reflective process, and if so, what are the requirements of its improvements?" (Hartley and Ravenscroft, 1993, p. 3).

The above researchers (Hartley and Ravenscroft, 1993) go on to describe a system called SCILAB, which was designed to explore one approach (for the domain of science) to providing dialogue that encourages reflection. The work described in this thesis has advanced on similar lines to SCILAB, i.e. we have inquired into one approach by which a computer system can be 'designed to assist the reflective process', but for the domain of musical composition.

1.3.2 Dialogue in musical composition learning

Musical composition in Higher Education (HE) has been chosen as the domain for investigation in relationship to the field of Artificial Intelligence in Education (AI-ED) for four related reasons, which we will now discuss in turn. First, musical composition in HE is one of the very few areas of teaching and learning that is most often carried out on a one-to-one basis. This makes it suitable for the Intelligent Learning Environment approach explored in this thesis (rather than, for example a Computer Supported Collaborative Learning approach). Furthermore, musical composition lends itself particularly well to the research described in this thesis because composition teaching and learning has started to undergo quite serious changes in its delivery and format. Specifically, composition is no longer an option in HE in the United Kingdom, but is a prerequisite of general musicianship (Morgan, 1994, personal communication). As such, composition education may benefit from access to computer-based agents for supporting dialogue and reflection in learning.

Secondly, musical composition is an open-ended, problem-seeking (Cook, 1994a, pp. 3-9) domain where there is often no single correct answer and where, as we have pointed out above, the seeking out of a problem to solve is a key to creativity. This presents AI-ED research with many problems. A key issue addressed in this thesis is the investigation (by theoretical deliberation, empirical study, interaction analysis and teaching agent construction) of the exact nature of the interactions that take place when a teacher supports reflection about creative intention in a small area of musical learning. Very little work has been done on how computers can be used in HE to support metacognition and explanation in the creative subject area of musical composition. Although a similar point was originally made in the late 1980s by Baker (1989) and Holland (1989), it nevertheless remains true today (Appendix 1 presents a small survey that supports this claim).

Third, making a judgement about a musical composition 'solution' is very much related to personal beliefs, intentions, goals and values as well as aesthetics. These issues present a challenging problem for AI-ED, which has tended to concentrate on more clearly defined problem areas such as maths and science. Sandberg and Andriessen (1997) have suggested that AI-ED research places too much emphasis on addressing these procedural domains, which can be easily formalised, instead of concentrating on the much harder matter of acquiring declarative knowledge and conceptual understanding. We would suggest that promoting problem-seeking in learners further compounds the difficulty faced by research that attempts to formalise such problem-seeking domains. Of course, this factor also makes problem-seeking domains interesting problem areas to investigate.

The fourth reason for studying musical composition is that the widespread use of computer-based sequencers in musical composition education has brought with it some problems. Sequencers are software based recorders of musical performance data that allow musical material to be assembled from the bottom-up, layer by layer. When using sequencers, a student composer may tend to engage in a cycle of playing, listening and editing. This process has a tendency to relieve the student composer of the need to memorise and internalise successively imagined musical material (Morgan, 1992). Traditionally, however, musical composition has always required the development of memory, reflection, critical judgement and analysis, all skills that require higher-order thinking about musical materials (Sloboda, 1985, p. 118). Thus, there is suggestive evidence that supports the view that the use of sequencers in the current training of composers in HE (the focus of this research is HE) appears to limit higher-order, metacognitive thinking in some learners. The previously stated problem is elaborated upon in Section 2.1.1.

1.3.3 Metacognitive processes relevant to musical problem-seeking

The term Intelligent Learning Environment or ILE (Self, 1993) refers to a particular type of agent-based learning environment. ILEs emphasise the role of higher-order thinking and have an objective of engaging the student in some goal-directed, problem solving activity that the ILE 'knows' something about (known in the sense that it is believed to be correct). ILEs place a stress on learning by reflection, i.e. metacognition. In the context of ILEs, Self (1993) has proposed a conceptual architecture that can be used as a common language when investigating interaction and metacognition. The architecture, called DORMORBILE (DOmain, Reasoning, MOnitoring and Reflection Basis for Intelligent Learning Environments), distinguishes four levels of agent knowledge for student modelling purposes. DORMORBILE provides a useful framework for conceptualising how interaction can take place with an ILE and is used in our work (see also Pilkington and Parker-Jones, 1996, for another example of its use).

Metacognition can be defined as the understanding of knowledge, an understanding that can be reflected in either effective use or overt description of the knowledge in question (Brown, 1987). By drawing on the four levels of DORMORBILE and a related paper (Self, 1992), it is possible to extend Brown's (1987) definition of metacognition and say that cognition and metacognition have four components: the domain and reasoning levels are the object level and equate to cognition. The monitoring and reflection levels are the meta-level, and are what we mean in this thesis by metacognition. Before a composer can engage in metacognitive (i.e. meta-level) activities they usually have to undertake extensive training in object-level cognition in areas as diverse as musical genres, notation, harmony, melody, rhythm, counterpoint and aural skills. However, the object-level is not the focus of this research (although acquiring such object-level knowledge will have probably entailed some meta-level activity at some stage).

An agent is, therefore, considered to have each of four levels. The *domain level* contains domain-specific knowledge (as in AI-ED learner modelling). It contains facts and concept definitions (e.g. "register is the range of a human voice or of a musical instrument") and rules (e.g. "a distinctive transition between two motives can be achieved by a change in some musical dimension like register"). The *reasoning level* represents processes that operate on the domain level to produce new elements in the domain level. One reasoning level process in music is 'local grouping boundaries' (Lerdahl, 1988). A grouping can be a musical motive, several motives combine to make a phrase or a section. The process of establishing local grouping boundaries (e.g. establishing a boundary between one phrase and the next) requires the presence of salient distinctive transitions at the musical surface (i.e. the hearer must be able to perceive a change in the music). Applying the reasoning-level process 'local grouping boundaries' (to achieve distinctive transitions at the musical surface) might involve the domain-level knowledge related to 'register', specifically that of getting the violin to take over the playing of a melody from the double bass in order to achieve a shift in register, and thus indicate the transition from one phrase to the next. The outcome of this reasoning-level activity is the rule 'changing instrument from bass to violin can achieve a distinctive transition', which could then itself be pushed down to the domain level. The *monitoring level* acts on lower levels. Thus, a monitor may ask of a reasoning-level process 'does repetition give rise to local grouping boundaries?'. At the *reflection level* we try, for example, to make generalisations, e.g. 'where else in my compositions can I use repetition to achieve a distinctive transition?' The outcomes of monitoring and reflection can be pushed down to lower levels. Thus, meta-level knowledge (reflection and monitoring levels) can get pushed down the levels to become object-level knowledge (reasoning and domain levels).

Creative reflection is a constrained type of metacognition that has been developed for the purpose of this thesis. Creative reflection is defined as the ability of a learner to imagine musical opportunities in novel situations and to then make accurate predictions (verbally) about these opportunities (the illustrative example in Section 1.4 provides an elaboration of creative reflection). An example of 'imagining a musical opportunity' would be an utterance like: 'I don't want to repeat the same note twice in my phrase'. To succeed at creative reflection there should be a correspondence between what a learner predicts will happen and what actually happens. An example would be a learner first writing a phrase using musical notation, then predicting verbally how that phrase will sound, then playing the phrase back on a piano and finally evaluating if the prediction was accurate or not. In the empirical study described in Chapter 5 of this thesis, a human teacher had an overall goal of supporting learner creative reflection. The teacher adopted a specific educational approach, termed "mentoring". Mentoring pedagogical goals were used by the teacher that intended to promote creative, metacognitive and critical thinking.

1.3.4 System design based on studies of human communicative action

Towards the end of Section 1.1 we claimed that educational research on interactions has tended to focus on a level of analysis and description that is of limited value for the types of models and theories that we wish to construct in AI-ED. This 'level of description claim' does not suppose that educational research is, or has been, carried out at the wrong level of detail. Rather, the claim is that the gap between the level at which educational research is conducted and the fine-grained detail required for AI-ED approaches has, up to the present, been too great to be bridged. Support for this claim can be found in the literature:

> "... most of this work [educational research on interactions] is descriptive and statistical in nature. It tells us that a teacher spends 40% of his or her time responding to student-initiated activity (or whatever) but offers no help in understanding the processes and mechanisms involved. Similarly, the nonquantitative work, based on sociological and anthropological approaches, is of limited value for the types of models and theories which we wish to construct in AI and education ... we must obviously look at education if we are to find out about educationally specific goals. It is not clear, however, whether we can derive the information we need from existing work. There is a large gap to be bridged in terms of levels of description. If the gap cannot be bridged, then it is necessary for AI and Education to include repetitions of previous research at finer levels of detail." (Elsom-Cook, 1991, pp. 76-77)

The use of dialogue data to inform AI-ED systems' design is an approach that some researchers have already used. The WHY system (Stevens, Collins et al., 1982) represented an early attempt, based on a study of human tutoring, to formalise the Socratic method for tutoring about the rainfall processes. However, the analysis of dialogues used to inform WHY may not have been systematic, as the researchers appear to admit:

"We will **use examples** from human dialogues ... [when] attempting to make concrete some of the issues raised ..." (p. 14)

"A **cursory examination** of our dialogues suggests that **a large percentage** of tutors' statements and questions fall into these categories [of the functional representations: actors, factors, functional-relationship and result]." (p. 19)

(Stevens, Collins et al., 1982, our bold)

The approach taken with respect to WHY, appears to have been one of using "examples" from the analysis of dialogues to raise issues, and one of making estimates about the number of intervention types that were attributable to a particular category ("a large percentage" of X are in category Y). This informal approach to dialogue analysis was then used to inform system design. WHY did, however, make a valuable contribution in that it was the first Intelligent Tutoring System (ITS) to try and make a teaching strategy explicit, although it gave no rules on how to change strategies. More recently, some of the WHY researchers have followed up their own work (Collins and Stevens, 1991) by proposing a theory of inquiry teaching based on further dialogue analysis. The TAP system (Wong, Looi et al., 1995) has implemented a dialogue planner based on Collins and Stevens' theory of inquiry teaching.

Rather than using dialogue data to provide illustrative examples, our own approach provides a systematic agent design method for educational systems in open-ended, problem-seeking domains. Chapter 2 (Section 2.3.2) will investigate in more detail the use of dialogue data to inform AI-ED systems' design.

1.3.5 Links between research background and this thesis

The problems outlined above in this research overview (in particular the musical problems 'thread' described in Section 1.3.2 and the dialogue analysis problems 'thread' described in Section 1.3.4) acted as motivation for the work that is described in this thesis. Specifically, in the case of 'mentoring dialogues, reflective engagement and musical composition in higher education', the focus of this thesis, no work of a similar nature was found in the literature (this assertion is backed up with evidence in Chapter 2 and Appendix 1); hence motivating our new and detailed empirical study described in Chapter 5. The arguments and problems described above also give a clear indication of why this research was conducted: to investigate, at a level of detail sufficient for building an artificial agent, how and why some kinds of dialogues promote reflective engagement in musical composition learning. Chapter 2 examines the relevant literature in more detail and explores the problems investigated in this thesis.

1.4 Illustrative example of a Knowledge Mentoring interaction

A small interaction is now described in an attempt to illustrate how mentoring interventions can occur to verify that a learner has engaged in creative reflection (the extract is taken from session 4 of the study described in Chapter 5). The following points should be noted about this example interaction. A few minutes before the interaction below, the teacher had asked the learner to create a phrase that was "radically different" to the learner's first attempt (i.e. to imagine an opportunity). The learner did this and entered (into the learning environment being used) a list of transposition values that would produce a musical phrase. The learner's list was: 0 8 1 7 -12 -5 0 -4 3 4 1 8 -10 -2 -1 (the Section 5.2.1 on Coleridge explains this in more detail). Briefly, the first four numbers in the list, which are the main subject of the dialogue below, would be played back by the computer, using a regular rhythm, as follows: 0 plays C C# F# G, 8 plays G# A D D#, 1 plays C# D G G#, and 7 plays G G# C# D. The teacher then asked the learner to describe the phrase to him (i.e. the learner was asked to make a prediction), an extract from the learner's prediction is given below (the teacher's comments have been taken out):

Learner: Err, well instead of being in groups of 4 [i.e. four notes to a motive], I've made it sort of groups of 8, in places. [PLAYS AN EIGHT NOTE MOTIVES ON THE KEYBOARD: C C# F# G G# A D D#.] Hopefully. Not sure if it's going to come out like that. Intervals of 8 and have two carrying on from each other, hopefully. And then there's just a couple of red herrings as well ...

Following a brief discussion about the learner's prediction, the teacher then played the musical phrase on the computer-based learning environment (which we describe in Section 5.2.1). The interaction shown below then took place (numbers in brackets are pauses in seconds):

Teacher: What do you think?

Learner: (1.0) It wasn't actually quite as (2.5) as I expected. But doesn't mean that

Teacher: What did you expect?

Learner: Err, I got mi, I got mi countin' wrong should be an 0 1 because I wanted it to have a sort of [PLAYS SCALE ON KEYBOARD: C C# F# G G# A D D#]

Teacher: Got your counting wrong. Yeah, so that's

Learner: I didn't want it to play the same note twice.

The first question by the teacher ("What do you think?") is a very open-ended question. The teacher is checking that the learner is really thinking about what he is doing (i.e. that he had an intention when he composed the phrase, that he is not just leaving everything to chance, that he had in fact imagined some opportunity). The learner pauses for one second before answering with an evaluative comment: "It wasn't actually quite as (2.5) as I expected". This comment itself has a longer pause of two and a half seconds embedded within it. The pauses may indicate that the learner really is thinking in some way about the question and his own creative intentions. The learner attempts to continue talking but the teacher interrupts with the question "What did you expect?". The teacher wants the learner to say why the phrase they have just listened to did not meet his (the learner's) expectations. Thus, the teacher appears to have established that the learner is thinking in an intentional manner, and now wants the learner to give an explanation about why the imagined opportunity, as specified earlier in the prediction, did not match the musical outcome (the phrase when played back on the computer). The learner responds to this continued line of questioning by the teacher with an explanation (a diagnosis) of why his phrase did not meet his expectations ("I got mi, I got mi countin' wrong ..."). The learner then plays something on the piano, the point he is trying to make is not yet clear. The teacher therefore attempts to encourage the learner to keep explaining by giving a repetition of the explanation previously made by the learner ("Got your counting wrong"). The teacher then starts to ask another question, however, the learner cuts the teacher short with an explanation of what he had intended ("I didn't want it to play the same note twice"). "It" in the learner's explanation refers to the learner's phrase.

Following questioning by the teacher, the learner has now given, verbally, a clear problem definition (of his creative intention). Although not shown above, discussion then took place between the teacher and learner in which it was clarified that the fourth note in the motive provided by the computer-based learning environment is 7 semitones above the first note (and not an interval of 8 as the learner states in his prediction above) and that it is not the 0 8, in the learner's list, that is wrong; the phrase should have a 9 (which plays A A# C# D) instead of the 7 (the first four numbers in the list would then meet the learner's creative intention of not playing the same notes twice in an 8 note motive). The learner went on to make the alteration to his list (changing the 7 to a 9). The teacher then commented favourably on the novelty of the learner's idea. The exchange shown above was, therefore, successful in helping the learner to compose in an intentional and reflective manner. That is to say, the mentoring interactions assisted the learner's attempts at creative reflection. By getting the student to verbalise how he predicted the phrase would sound, and by the use of focused questioning to find out if the student was composing in an intentional manner, the teacher used mentoring interactions to support the student's attempts at building a stronger image of his imagined opportunity.

1.5 Evolution of the thesis

The research approach adopted in this thesis has been one of conducting four studies within an iterative, user-centred design context. This iterative approach is illustrated in Figure 1.1. Because the first two studies conducted for this research project are not reported directly in this thesis (they are available as a publication and a technical report) we will now describe these two studies below. We also briefly mention both a survey that was conducted as part of this research and the second two of the four studies.

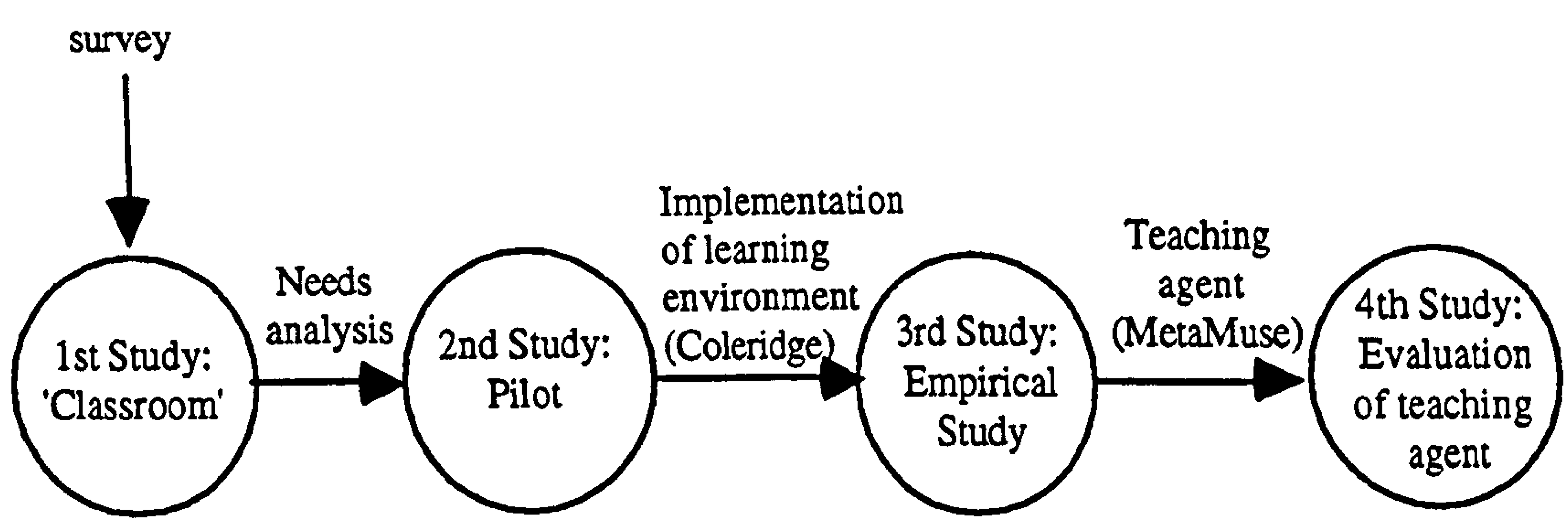

Figure 1.1. Iterative approach of this thesis.

In the second half of 1993, a small number of musical cognition and musical education researchers were contacted by letter for help with various research questions related to this research project (the survey shown on the top left of Figure 1.1). The replies from these experts gave this project the impetus to go on to conduct detailed, and new, research in the area of metacognition in musical composition education. This survey is summarised in Appendix 1.

The first study shown in Figure 1.1 involved the systematic observation of three timetabled composition tutorials. The sessions took place in a British University in the south-east of England during February and March 1994. This study was written up and published in Cook (1996a). Although the analysis was selective (i.e. no systematic analysis took place), many of the teaching interactions in this first study were found to rely on critical dialogue at the expense of guidance on the creative process (a suggestive finding that was also supported by the survey). This led to the conclusion that there was a need to conduct studies that specifically examined metacognition in musical composition education.

The second study shown in Figure 1.1 involved three specially designed (for the purposes of this research) teacher-learner sessions and took place on 18 March 1994, at a Department of Music in a University college in the north-east of England. The Technical Report (Cook, 1994b) describes this pilot study. On the basis of various considerations raised by the second study, a computer-based learning environment called Coleridge (which we describe in Chapter 5) was designed[9] to provide the fast playback of musical ideas, thus freeing up time for interaction and metacognition. The second study was also used to propose a description language, which was described in Cook (1996b) and which is not reported in this thesis because it developed an approach to interaction analysis that has not so far been exploited in computer-based teaching agent design.

The third study took place at a University college in the north-west of England, in November 1996 and involved four specially designed teacher-learner sessions with Coleridge. This study, and the related interaction analyses, are described in detail in Chapter 5 of this thesis. The empirical data generated by the third study (which will be referred to as the 'empirical study') was used to inform the design and implementation of a computer-based teaching agent called MetaMuse, which is described in Chapter 6. The fourth study shown in Figure 1.1 was conducted at a Department of Music in a University College in the north-east of England. The fourth study was a formative evaluation of the MetaMuse teaching agent with four musical composition teachers and one AI-Music researcher, and is described in

[9] Coleridge was developed by Cook in collaboration with an experienced composer-teacher (Nigel Morgan). An extended description of Coleridge can be found in the ALT-J article: Cook and Morgan, 1998.

Section 6.5.

1.6 Overview of the structure of the thesis

A literature review is presented in Chapter 2 that further investigates the musical, higher order-thinking and dialogue threads introduced above in Section 1.1. Chapter 2 also provides a review of aspects of agent theory that have a direct bearing on the agent implementation described in Chapter 6. A summary of the literature review is provided in Section 2.5. In Section 2.6 we draw some conclusions from the literature in terms of the problems that were highlighted and their link to the argument being made in this thesis.

In Chapter 3 we describe our theoretical framework, called the Knowledge Mentoring framework, for designing computer-based teaching agents that are capable of supporting musical composition learning. This theoretical framework was briefly introduced above in Section 1.2.1.

The research approach and methods used in this thesis are elaborated upon in Chapter 4. The research approach used was an iterative, user-centred design approach. The research methods that were used for the empirical study, described in Chapter 5, was a combination of complementary methods, involving systematic observation, post-experimental interviews, data transcription and qualitative data analysis to generate quantitative data. The research approach and method used for the formative evaluation of the teaching agent were, respectively, Cooperative Evaluation and questionnaire.

Chapter 5 describes the analysis of empirical data and is divided into five sections. Following the introduction, the second section describes an implemented prototype computer program ("Coleridge") that enables learners to construct musical phrases. Coleridge is a learning environment that was designed, in collaboration with a composer-teacher, to provide the fast playback of musical ideas, thus freeing up time for interaction and metacognition. Section 5.2 also describes an empirical study. The study used Coleridge to investigate the way in which a human teacher supported higher-order, musical thinking in learners. This involved the collection of a corpus of student-teacher dialogues in the domain of higher education musical composition. The study involved four sessions. In each session a teacher and one student interacted with each other and the computer-based learning environment (Coleridge). Section 5.3 describes the design of seven complementary approaches to detailed analysis of the dialogue interactions. By using a theoretical framework derived from the literature, i.e. the KMf, the interaction analysis described in Section 5.3 proposes a categorisation of data (transcriptions of the sessions) into goals and communicative acts. Frequency counts were to be generated for each category. Further approaches to the analyses of this categorised data are described in Section 5.3. The results from applying the seven analyses approaches are reported in Section 5.4. We conclude Chapter 5 in Section 5.5 with a discussion of the implications of these results for computer-based teaching agents. Section 5.6 summarises the results.

The design, implementation and evaluation of a pre-prototype human-machine dialogue system called MetaMuse is described in Chapter 6. A pre-prototype is limited in what it can do because it only incorporates one or two features of a full system. MetaMuse was integrated with Coleridge and was also based on both an extension of existing computational model of rational agents (Blandford, 1991) that is capable of engaging in dialogue, and the results obtained from qualitative and quantitative analysis of the dialogue corpus (i.e. Section 5.4). A formative evaluation of MetaMuse with mainly teacher-composers is presented. The evaluation suggested that MetaMuse may be able to promote creative reflection in learners.

Chapter 7 presents the thesis contributions, conclusions, limitations and future work. It describes the claims and contributions made by this research, assesses the impact of this research on musical education and AI-ED, provides an outline of the limitations of the research approach and methods used in this thesis, and describes future research directions.

The work reported in this thesis has been communicated and published in various posters, reports and papers[10].

[10] (Cook, 1993; Cook, 1994a; Cook, 1994b; Cook, 1994c; Cook, 1994d; Cook, 1994e; Cook, 1995a;

Our overall approach to teaching agent design is called 'Knowledge Mentoring'. Throughout the remainder of the thesis, we shall consistently use the following terms in order to avoid confusion:

- "theoretical framework" [TF] will be used to refer to the Knowledge Mentoring framework (KMf) described in Chapter 3,
- "analysis techniques" [AT] will be used to refer to the seven approaches to analysis of the empirical data described in Section 4.2.2 and Section 5.3,
- "computational model" [CM] will be used to refer to the full design of the teaching agent presented in Section 6.2, and
- "computational implementation" [CI] will be used to refer to MetaMuse, the computational model instantiated in a specific case of mentoring creative reflection in musical composition (described in Section 6.3).

Cook, 1995b; Cook, 1995c; Cook, 1996a; Cook, 1996b; Cook, 1997a; Cook, 1997b; Cook, 1997c; Cook, 1997d; Cook, 1998; Cook and Morgan, 1998).

Chapter 2 - Research Context and Problems

A literature review is presented in this chapter that further investigates the musical, higher-order thinking and dialogue threads that were introduced above in Chapter 1. Problems that are relevant to this thesis work will be raised. The literature which forms the theoretical basis to the approach to interaction analysis and agent design used in this thesis is also described. Section 2.1 examines the musical composition learning literature (both face-to-face and computer-based). In Section 2.2 we describe the higher-order learning literature and review some AI-ED systems that have attempted to support higher-order thinking. Section 2.3 provide a review of the literature relating to speech acts, communicative acts, and goals. Approaches to linking interaction analysis to system design are also reviewed in Section 2.3. In Section 2.4 we review aspects of agent theory that is directly relevant to this thesis (i.e. that have a direct bearing on the computational model and computational implementation described in Chapter 6). In Section 2.5 we summarise the literature. Finally, in Section 2.6 we draw some conclusions from the literature in terms of the problems that were highlighted and their link to the argumentative claim being made in this thesis (see Section 1.1.3).

2.1 Musical composition education and related problems

This section examines aspects of the musical composition learning literature that is most relevant to this thesis. Some systems that have attempted to support musical composition learning are then reviewed.

2.1.1 The musical composition education literature

No consensus exists on how to teach musical composition. Approaches can include the traditional, one-to-one apprenticeship to a teacher-composer (Austin and Clarke, 1989, p. 1) and the jazz workshop approach where 'band arrangement' acts as a vehicle for learning about composition. Similarly, in higher education in Britain and Ireland, there is no consensus on 'what' aspects of composition to teach: "some university music departments have abandoned techniques teaching altogether - those where it is retained being seen as bastions of conservatism" (Johnstone, 1996, p. 247). This section looks at the issues involved in understanding 'how' to teach and 'how' students learn composition from a (mainly) cognitive perspective and raises some related problems.

2.1.1.1 Musical cognition

Research into cognition in the domain of music is growing area. Composing is a hard cognitive task, requiring an overall conception of the compositional goal and an ability to move to and from a small and a big picture. Research examining reflection in school children as a dimension of the skill of divergent thinking in music (Schmidt and Sinor, 1986) has concentrated on aspects of improvisation. However, some researchers draw a clear distinction between the processes involved in composition and improvisation (Sloboda, 1985; Kratus, 1989), and between models of the product and of the process of composition (Kratus, 1989; Candy, 1992).

Some of the musical processes involved in composition are reasonably well understood, for example those of transforming, extending and developing a theme. There is agreement (Sloboda, 1985; Swanwick and Tillman, 1986; Davidson and Welsh, 1988; Christensen, 1992; Colley, Banton et al., 1992) that some 'superordinate' structure or reflective cognition guides the psychological activity of musical composition, i.e. considerations of large-scale structure and planning that guide choice on a note by note basis. However, there is some disagreement in the research about the nature of the processes involved in composition.

Sloboda (1985, Chapter 4) describes in great detail the evidence that exists about the compositional process and proposes, based on what he calls "agreement across accounts" (Sloboda, 1985, p.116), that there exists two stages in composition. The first stage is called 'inspiration', where a theme or idea appears in consciousness; the second is called 'execution', where the theme or idea is worked on in a more conscious way by extension or transformation. This does not, however, explain how a skilled composer works. Sloboda proposes that a 'superordinate' structure guides the psychological activity:

> "It seems to me that the choice of the 'right' development may be governed by considerations of large-scale structure and balance ... The art of composition lies, in part, in choosing extensions of initial thematic ideas that honour superordinate constraints, often to be formalised in terms of hierarchical structures governing sections or movements." (Slòboda, 1985, pp. 116-117)

Superordinate cognition acts as a guide to the detailed note-by-note working out. Sloboda (1985, p. 117) suggests that this process may be akin to the general theory of problem solving postulated by Newell, et al. (1962). This general account of heuristics for solution-generation and verification may, however, have its limitations in the open-ended creative domain of composition. This is because heuristics (if viewed as foolproof solution generators) suffer from the same limitations as grammars, in that they may only be useful in certain circumstances but may not tell the whole story. Furthermore, as Sloboda puts it, "heuristics are not perfect, there has to be a process of verification whereby trial solutions are tested against criteria for success". (Sloboda, 1985, p. 117)

Work by Swanwick and Tillman (1986) identified metacognition as the highest level in their study of musical development in children's composition (self-awareness of the processes of thought and feeling in response to music). Metacognition for these researchers involved the symbolic and then the systematic mode of development. Symbolic in the sense that Bruner (1966) meant it: an increasing capacity to say to one's self or others, by means of words or symbols, what one has done or what one will do. The idea of being able to say what one will do is similar to the creative reflection concept (which was defined in Section 1.3.3 as the ability of a learner to imagine opportunities in novel situations and to then make accurate predictions about these opportunities). Saying what one has done is a function of metacognitive-monitoring (Section 2.2 will expand on this point).

Sloboda (1985) and Kratus (1989) suggest that problem solving may account for some of the processing involved in composition (although Sloboda has reservations, as we saw above, and the Kratus study is of school children). Davidson and Welsh (1988) see compositional activities in higher education in terms of an inquiry: hypothesise, test, try out in context, and evaluate. Colley et al.'s (1992) view is that the expertise in higher education students' compositions are similar to expertise in other domains. Colley et al.'s finding contradicts Davidson and Welsh, who found that composition expertise was different to, say, chess playing expertise. The fact that superordinate or reflective modes of thinking about the composition process is not as well understood as some of the other processes involved in music makes it a strong candidate for detailed exploration by research. Having an overview of the big picture can prevent a composer from getting stuck with a motif, stop the composer going down blind alleys, help the composer decide when to throw away a bad idea or keep a good idea, and help the composer come up with a coherent piece.

2.1.1.2 The Davidson and Welsh study

Since their study was in higher education and because their findings on reflection are relevant to our research, we will now consider the work of Davidson and Welsh in some detail. Davidson and Welsh (1988) combined the use of protocols and research into developmental psychology to provide useful data on the skill of composition. The study focused on the processes by which music performance students of differing levels of expertise construct a melody given certain constraints that the melody must follow. Two groups of students were used: a 'beginner' group (first year conservatory students) and an 'experienced' group (who had completed two years of training at a conservatory). The subjects were given the task of producing a melody that used a rhythmic pattern that was provided and which modulated twice (C major, to F sharp major, and back to C major). Their analysis of the results seemed to show that the experienced group were able to work with larger units, for example they were able to play over large sections. The experienced group were also able to engage in *more reflection.* For example, they were able to evaluate their decisions before committing them to paper, they were able to define their goals before starting to work, and they were aware of the shape of the melody as they worked:

"Their tonal knowledge was integrated into a rich and flexible working system. They had an understanding of tonality which included awareness of how scale degrees functioned and how even distant key areas could be related." (Davidson and Welsh, 1988)

The beginner group on the other hand worked in a more enactive note by note fashion, with little awareness of how the melody was evolving. For example, beginners would try out possibilities at random until something was found that worked. The study also highlighted the fact that gifted performers of music do not necessarily make the best composers. The compositional strategies employed by the more successful students included the use of melodic shapes, contours, and motives:

"Characteristically, individual decisions at the note-by-note level are assessed in terms of their overall effect on the design. These students' ability is evident from the use of a hypothesis-testing model throughout the task. The model appears to have four steps, *hypotheses, test, try out in context,* and *evaluate* (accept or reject)." (Davidson and Welsh, 1988, p. 279)

Davidson and Welsh suggest that there is an emerging consensus (one that has implications for this thesis):

"The use of melodic motives is not only a powerful means of achieving structural unity and contrast, but their use also reflects the ability to think in larger structural chunks." (Davidson and Welsh, 1988)

On the basis of the above finding, we choose to focus on the use of a motive[11] in the work described in Chapter 5 of this thesis.

2.1.1.3 Problem-seeking

The considerations highlighted so far in this section give rise to the following question: what kind of reflection is appropriate for creative problem solving? Einstein and Infeld have speculated on this notion:

> "... the formulation of a problem is often more essential than its solution, which may be merely a function of mathematical or experimental skill. To raise new questions, new possibilities, to regard old questions from a new angle, requires creative imagination and marks real advance in science." (Einstein and Infeld, cited by Getzels and Csikszentmihalyi, 1976)

If we act on Einstein and Infeld's insight regarding reflection on "the formulation of a problem", another question presents itself. Namely, can we fruitfully use standard problem solving techniques as an approach to teaching musical composition? As we saw above, Sloboda has his doubts. McAdams and Bigand (1993, p. 4) have pointed out that although the psychology texts do cover problem solving and reasoning, the coverage is never related to "auditory problem solving as might be involved in musical composition". Creative reflection (as defined above) is more than making accurate prediction in say Physics, where if you have a model of the domain you can then make predictions (inferences) about what will happen in certain circumstances. Clearly, creative reflection adds the requirement for creativity. Science text-books have a tendency to treat scientific knowledge as settled. A student learns standard approaches to problem solving. The student is then given problems that vary from the model to see if they are able to extrapolate from that model of how things should be done to solve the problem in hand. In the humanities and arts, however, Lipman (1991) has suggested that the subject matter itself is treated as

[11] A motive (or motif) is the briefest intelligible and self-existent melodic or rhythmic unit. It may be of two notes or more. Please refer to the glossary for other musical terms.

essentially problematic and that it is more a question of problem-seeking than problem solving (Lipman, 1991, p. 175). Lipman is probably correct in his assessment of many science text-books, which tend to say things to the effect: here is theory X, which has replaced theory Y as a way of interpreting the physical world. However, Lipman is perhaps too brief in his argument and does not mention recent changes in science and maths teaching (see Schoenfeld, 1985; Hartley, Byard et al., 1991 for example). Nevertheless, we have extended this notion (Cook, 1994a) by proposing that in creative reflection about problem solving, the first stage is often to problem seek, i.e. to define, formulate, find, invent, or create the problem before a method for arriving at a solution can be identified.

There is further support for the notion of problem-seeking in the literature. Some research into the subject areas of fine art (Getzels and Csikszentmihalyi, 1976), maths (Smilansky, 1984) and music composition (DeLorenzo, 1989) suggests that *problem-seeking,* or finding a problem to solve, may be a stronger indicator of true creative behaviour than the actual problem solving process. For example, in a longitudinal study of artists and the creative process Getzels and Csikszentmihalyi (1976) showed that young artists whose cognitive approach emphasises problem-seeking (they called it problem finding) over problem solving were more successful in their creative careers. The claim being made here (which builds on the claims made in Chapter 1) is that problem-seeking is relevant to many creative problem solving activities, e.g. in the sciences and the humanities, and should be emphasised when designing computer-based teaching agents in open-ended domains like musical composition.

2.1.1.4 Musical auditory and memory structures

To understand how knowledge about music composition is learnt, we must also take into account work on audition. McAdams and Bigand (1993) have recently presented a theory of auditory cognition. As the authors point out, "no theory of knowledge is complete without a theory of its acquisition":

> "Etymologically speaking, the term 'cognition' refers to the notion of knowledge. It has been used in a more specific sense to designate the conditions that allow humans to develop knowledge of the world. It almost goes without saying that no knowledge can be acquired in the absence of perceiving: in other words, no theory of knowledge is complete without a theory of its acquisition, and thus of perception. To emphasize the cognitive aspects of audition is thus primarily to remind us that auditory information participates in a fundamental way in the development of knowledge." (McAdams and Bigand, 1993, p. 1)

Auditory knowledge, therefore, is important when accounting for the acquisition or learning of knowledge in general, and is hence important twice-fold when related to the learning of music composition knowledge. A composer needs to consider how the listener 'hears' what has been composed (if they wish to communicate musical ideas to a wider audience at any rate).

Earlier studies (Morgan, 1992; Cook, 1994b) have found that some learners tend to have poorly developed recall abilities of the structure of a musical piece that they have created, or of a piece they have just heard. On the basis of these restricted findings it is possible to claim that, for some learners, sitting at the computer and using computer-based sequencer programs (described in Section 1.3.2) to compose with may be the cause of a *problem*. It appears that some students may tend to let the sequencer do much of the work and do not develop creative reflection abilities and memory recall of composition structure abilities. In one of the earlier studies, Morgan (1992), the action research method was used to observe twelve successive students working with a sequencer to compose. The subjects were 2nd and 3rd year BA (Hons) Music students who were studying composition. The teacher-observer (Morgan) only answered technical questions from the students. In post-observational questioning, it was found that the students had poor memory recall of the structure and the detail of a piece they had just been working on. The finding that learners have poor recall of a piece they have just heard is supported by the interview extract below, which is taken from a post-experimental interview with a teacher in a pilot study (Cook, 1994b) that was conducted for the research reported in this thesis (see

Section 1.5 for an account of the various studies that have been conducted as part of this research project):

> **Teacher:** The way she heard it. Err, and it was, I was a little taken aback by her first response. That's why I asked her to do the drawing. And I was interested to see, when she was doing the drawing, that she was thinking very much in phrases rather than in section structures. Her memory, I was very conscious, that her memory was not very well developed in that respect.

The initial argument for the use of computers in musical education was that the computer would do the mechanical work, freeing up cognitive capacity for the student to reflect (i.e. for metacognition). What we are claiming here is that this reflection does not automatically then take place (when using a sequencer); the student has to be encouraged to reflect in some way.

Why should memory play an important part in music composition learning? Sloboda (1985, p. 190) suggests that if listeners do not develop the appropriate internal 'mnemonic' to link elements of the structure of a composition together, the limits on memory will not be overcome (i.e. normally we can memorise no more than about ten unrelated musical items). Boden (1990) has pointed out that one reason why Mozart was so successful a composer was that he

> "had a more extensive knowledge of the relevant structures. Memory ... stores items in the conceptual spaces within the mind. The more richly structured (and well-signposted) the spaces, the more possibility of storing items in a discriminating fashion, and of recognizing their particularities in the first place ... someone who knows nothing about tonal music cannot interpret the sounds of a Western folk-song as a melody, nor recognize a modulation or a plagal cadence. (They need not know the technical terms; but verbal labels sometimes help to 'fix' schemas in the memory.) In short, Mozart's exceptionally well-developed musical memory was a crucial aspect of his genius." (Boden, 1990, pp. 252-253)

McAdams and Bigand (1993, p. 2) have elaborated on this idea of structures within the musical mind and have proposed that because "sound events are events that succeed one another in time", when a composer engages in auditory problem solving, her or his perception of the structure of the sound events "requires the elaboration of a mental representation in order to be able, subsequently, to establish relations among events that are separated from one another by several minutes or even hours." Music offers a typical example here:

> "how can we perceive the unity of a sound structure that develops over a very long time-span (one and a half hours in the case of Beethoven's ninth Symphony) without elaborating representations of the substructures (thematic ones, for example) that are developed in the work?" (McAdams and Bigand, 1993, p. 2)

2.1.1.5 The role of dialogue in musical learning

How, then, do we learn how to build these memory structures? Although a study of school children, Auker's (1991) investigation of the interactions between school teachers and pupils is of relevance in that he attaches great importance to such teaching-learning interactions. The interaction analysis technique used by Auker is somewhat discursive, however, it still revealed some useful findings:

> "I strongly believe that a better product will in fact emerge if we take seriously the role of language in the music lesson, because, lacking the musical vocabulary which allows a professional composer (for example) to think directly in terms of musical sounds, it is through spoken language that children can begin to explore and share what they have to offer in terms of musical creativity." (Auker, 1991, p. 166)

Auker makes a key point above, learners should be helped to develop the appropriate spoken language, which they can adapt and take ownership of as they begin to internalise and reflect on creative opportunities, and hence build the appropriate mental structures of their creative intentions. Hughes (1996) has extended the link between verbal interaction and musical composition development for nursery and school children. Hughes proposes a strategy for enhancing learning opportunities based on a theory of applied psychology.

The implication from the literature seems to be that a composer needs a well developed memory and the ability to visualise and make predictions about the structure of a planned composition if they are to compose successfully (e.g. to develop themes over a long piece). It also appears that some students may tend to let the musical sequencer software tools do much of the work when composing and, consequently, do not develop creative reflection abilities and memory recall of composition structure abilities. This would seem to suggest the need for the practising of 'creative reflection' in a learning situation, which was defined in Chapter 1 as the ability of a learner to imagine opportunities in novel situations and to then make accurate predictions about these opportunities. We also conclude that there is a need for studies that investigate how dialogue in higher education can assist musical creative reflection.

2.1.2 Systems for supporting musical composition learning

The literature describing how computers can be used to support musical composition creative reflection in higher-education is very small. We will therefore review a restricted number of systems that raise issues that are relevant to our own thesis. LOCO (Desain and Honing, 1986) is an environment that provides a set of composition microworlds that define different viewpoints on LOCO's conception of composition. LOCO provides a rich environment that is suitable for creative exploration and which is based on a well-understood AI technique of grammars. LOCO does not give tutorial guidance on how to compose (indeed it would not claim to), instead it provides 'cognitive hooks' (Elsom-Cook, 1990, p. 4) in the environment for students to 'hold on to' and learn (e.g. icons or objects in the interface). This approach has various drawbacks. Firstly, the gap between a novice learner and the environment may be too large to 'hang on to' (Elsom-Cook, 1990, p. 6-7). Secondly, to facilitate the learning of reflective skills LOCO would need to somehow store information in the interface about a set of goals to achieve these skills and to make directly accessible the deep semantics of such skills (Elsom-Cook, 1990, p. 6).

An Intelligent Tutoring Systems (ITS) intended to teach harmony has been proposed by Fenton (1989). Fenton's design proposal appears to make the assumption that there is a correct body of knowledge to be communicated (i.e. the assumption seems to have been made that if we teach X facts then Y content, then the student will then be able to compose) and is limited by its single representations of music knowledge (which can lead to a tendency to represent the student as a subset of the expert or the domain representation). While disagreeing with the suggestion that there is a correct body of musical knowledge that can be communicated, we would, however, accept that there are times when allowing students access to such an ITS to practice cognitive skills relating to harmony, and other techniques, could be justified. For example CALMA or Computer Assisted Learning for Musical Awareness (Pengelly, 1998) is, as the name suggests, a CAL (Computer Assisted Learning) package for aural training (for composers and performers) in HE that aims to enhance a student's responsiveness to aspects of sound such as timbral variation and intonation. CALMA aims to improve a listener's critical response to music and aural imaging by providing a CAL system that allows students to practice aural skills.

The proposed Music Composition (MC) architecture (Holland, 1989; Holland, 1994) includes a microworld environment called Harmony Space. In MC the music knowledge representation directly reflects the teaching strategy of constraint satisfaction. Such a tight relationship between teaching knowledge and music knowledge may inhibit the future addition of teaching methods other that the informal approach adopted. The music plan level of the MC architecture provides a useful structure for developing reflective skills, but does not embody teaching knowledge in terms of the goals and deep semantics that would enable it to justify its approach to teaching reflective skills. Baker (1989) describes a system called KANT for interactions revolving around the identification of phrase boundaries for very restricted musical genres. KANT attempts to engage in explicit negotiation strategies (based on dialogue games) with the aim of promoting metacognitive thinking (belief revision) in learners and critical arguments in dialogues about music. Consequently, Baker's work is close to the research themes of this thesis. However, as Blandford has already pointed out with respect to KANT:

> "the extent to which such aims [of promoting metacognitive thinking and critical arguments] are achieved cannot be established since KANT has not been empirically tested." (Blandford, 1991, p. 298)

However, Baker (1989) did not claim to have shown that anyone had learned from KANT. Baker did, however, contribute to AI-ED by proposing an original dialogue model for negotiating and arguing. Furthermore, KANT's dialogue model is appropriate for the type of open domain being explored in this thesis.

Two possible approaches to applying AI to creative domains such as composition seem to be emerging (although no teaching agent for supporting musical composition learning have been reported). The majority view (Boden, 1990, for example) is concerned with computationally modelling creativity in an attempt to gain some psychological insight into the processes involved. In this approach it is argued that creativity is the exploration and transformation of conceptual spaces, which are defined as a space of structures (tonality for example) that are defined by the rules of a generative system. A creative idea requires us to think the impossible or to 'break out' of the conceptual space by changing the rules that define it. A second approach (Candy, Edmonds et al., 1991, for example) is to address the issue of supporting creative activities in order to understand the processes involved. AI models of creativity offer insight but this is only part of the story (in our own research we have the added problem of how to teach in the domain). A prototype AI tool for supporting musical novices' learning of melody has been proposed by Smith (Smith and Holland, 1994) as part of his doctoral thesis work. Smith has developed a computational model of Narmour's (1990) Implication-Realisation Model. However, because no teaching agent has been developed and evaluated, it is difficult to assess the educational usefulness of the approach taken by Smith.

The research reported in this thesis takes what can be described as a third approach to applying AI to creative domains. Like Candy's second approach, this research aims to provide a tool (specifically a teaching agent) to support creativity. However, in our third approach the tool is based on empirical data of humans interacting. An empirically based computer-based model of a teaching agent that aims support creative reflection through interaction has been constructed and evaluated with users (Chapter 6 describes this work[12]).

2.2 Higher-order thinking

This section first examines the literature on higher-order learning concerning: cognition, metacognition, critical thinking, and mentoring. Some AI-ED systems that have attempted to support higher-order learning are then reviewed.

2.2.1 The higher-order thinking literature

The term higher-order thinking is a catch all phrase that is used to describe a large body of literature that relates to cognition, metacognition, critical thinking, and mentoring. Below we explore this literature from the perspective of the themes that are relevant to this thesis.

2.2.1.1 Cognitive concepts in learning

Before discussing cognition and metacognition, we first need to define what is meant (in this thesis) by knowledge and learning. The reason for this is that cognition, metacognition and mentoring tend to be discussed in terms of knowledge. Knowledge can be either declarative (facts believed to be true) or procedural (the processes we use to perform a task). Sternberg has gone as far as to say that knowledge may even become entrenched in that

[12]It should be noted that our computer model is not in itself capable of being creative or reflective.

"too much knowledge can lead to an entrenched perspective on problems. In other words, one becomes so used to seeing things in a certain way, it becomes difficult to see them in any other way." (Sternberg, 1994, pp. 224)

Thus knowledge is related to solving problems, a point that will be returned to below. One definition of learning is that it refers to

"the acquisition of knowledge through interactions with, and observations of, the physical world and the creatures that inhabit it." (Ashman and Conway, 1997, p. 1)

However, this raises an interesting question: does all learning have to take place through interaction with or observation of the physical world? Some perspectives, e.g. situated learning (Brown, Collins et al., 1989) and radical constructivist (von Glaserfeld, 1984) ones, suggest that learning depends upon interaction with the outside world. Some traditional cognitive scientists, on the other hand, might feel that all learning resides in the mind. A reasonable perspective has been proposed by Goodyear (1991) who has pointed out that ideas on the nature of teaching must be seen as constantly changing, and that we need to shift focus

"towards higher level skills - to "knowing how to find out," to generalized problem-solving strategies, to collaborative work and communicative skills." (Goodyear, 1991, p. 4)

The topic chosen for study in this research thesis is *fostering creative reflection through mentor-guided interaction,* and in this sense we would agree with Goodyear. However, in our work, by using teaching knowledge to encourage a learner to reflect on what they are doing, we are not only shifting the focus to higher level skills, we are also placing more emphasis on the learner.

Since the mid-1980s, there has been a growing awareness of the need to move from a teaching focus to a learning focus (Ashman and Conway, 1997). The movement has been away from knowledge supplied by the teachers and towards 'talking, reflecting and explaining' as ways to learn. The change in approach is exemplified by the 'self-explanation' work of Chi, de Leeuw et al. (1994) who describe an approach to 'talking' science rather than a 'hearing' science. According to Chi and co-workers, generating explanations to oneself (self-explanations) facilitates the integration of new information into existing knowledge. In the context of learning, the participants' relationship or attitude to knowledge could be (i) that knowledge is seen as an outside 'given' to be absorbed or transmitted, or (ii) that knowledge is co-constructed by teacher and learner, allowed to be queried, not 'true' for all time (Perrott, 1993). Thus, the concepts underlying what people mean by 'teaching knowledge' can range from that of knowledge communication (Wenger, 1987), to knowledge construction (Valsiner and Leung, 1994), or to some position in-between. In an attempt to bring clarity to this section of the literature review, Table 2.1 summarises some of the cognitive concepts presented in this section, many of these definitions are taken from Ashman and Conway (1997).

Problem-solving is an important component of education, and refers to the application of knowledge to achieve a desired outcome. For example, a student will use problem solving to get through exams at university, to collaborate successfully in groupwork, to negotiate with a tutor a higher grade for an assignment. Generally, learning refers to obtaining knowledge whereas problem-solving refers to the use of knowledge. However, it was pointed out above in Section 2.1.1 that, although the psychology texts do cover problem solving and reasoning, the coverage is never related to auditory problem solving as might be involved in musical composition.

Table 2.1

Cognitive concepts

Cognitive concept	Summary
Knowledge	Declarative, procedural or entrenched.
Learning	The acquisition of knowledge through talking and reflecting.
Teaching knowledge	A continuum between knowledge communication and knowledge construction.
Problem-solving	The application of knowledge to achieve a desired outcome.
Fact	Proposition believed to be true.
Information	A relationship between facts.
Strategy	Way of organising information so that its complexity is reduced, and/or integrating information into the knowledge base that exists in the brain for later use.
Plan	Complex routines that relieve the cognitive burden of the day-to-day activities. Planning is the development of a sequence of actions, or the sequence itself (e.g. a plan). May be opportunistic or long-range, etc.
Cognition	Refers to knowing and thinking. Cognition develops knowledge and makes sense of the world. It is a fusion of brain activities that include: attention, affect, coding, memory, 'metacognition', learning, problem-solving and planning.
Memory	Refers both to the 'place' where information is held, and also to the stored information.
Affect	The disposition one brings to learning. Includes motivation and emotion.
Attention	Involves sustaining interest and selectivity.
Mediation	Refers for the need for someone other than the learner to translate knowledge about the society and culture so that it can be internalised by the learner.
Internalisation	Refers to the individual's 'ownership' of concepts or meaning that have been provided through instruction. That is, learners must comprehend meaning and integrate the knowledge into their own thinking. This will involve a transformation of external stimuli to internal 'codes', that are consistent with their own knowledge base by changing and modifying the original ideas, and then applying their unique cognitive character to them.

Cognition is the process that develops knowledge and makes sense of the world. Cognition can draw upon cognitive resources such as memory, attention and perception. (See Brotherton, 1991, for a detailed review of adult cognition and learning and Table 2.1 for definitions of these concepts.) Another important cognitive concept is that of 'strategy', which is made use of by knowledge. In cognitive psychology, a strategy is taken to be

> "a conscious or automatic cognitive act, or systematic routine that enables information to be stored in, or retrieved from memory ... The main point here is to understand that strategy is a way of organising information so that its complexity is reduced, and/or integrating information into the knowledge base that exists in the brain for later use." (Ashman and Conway, 1997, p. 43)

2.2.1.2 The difference between cognition and metacognition

What is the difference between metacognition and cognition? The answer is not simple and there has tended to be much interchange in the usage of these terms in past research (indeed, the definition of cognition in Table 2.1, which is taken from Ashman and Conway, includes metacognition as part of its definition). Cognition refers to knowing and thinking, the construction of knowledge of the outside world:

> "it involves taking in, storing, retrieving, transforming, and manipulating information that is obtained through the senses. It also involves perception, awareness, judgement, the understanding of emotions and of course, memory and learning." (Ashman and Conway, 1997, p. 41)

Asking yourself questions about a piece of music might function either to improve your knowledge (a cognitive function) or to monitor it (a metacognitive function) (Brown, 1987, p. 66). For example, identifying the chord sequence performed at the end of a composition would be a cognitive activity, realising that the wrong sequence had been played would be a monitoring-metacognitive activity, or recognising that the chord sequence is appropriate and could be used in a composition you are currently working on is a reflective-metacognitive activity. Because of the diverse historical roots of the family of concepts that are often referred to generically as metacognition, in this research the term metacognition is limited as referring to the

> "understanding of knowledge, an understanding that can be reflected in either effective use or

overt description of the knowledge in question." (Brown, 1987, p. 65)

In Chapter 1 we extended the above definition to view thinking as split between the meta-level and the object level (see Section 1.3.3). We can take the above definition of metacognition even further if we consider, as Brown suggests above, that it includes a requirement for statable understanding of knowledge. Du Boulay (1996) has pointed out that there is a current trend in AI-ED research to examine two related aspects of learning. First we have internal dialogue (cognition in learning). Du Boulay proposed that there are three elements to internal dialogue: non-verbal self-explanations, monitoring and metacognition (which are loosely coupled to the external dialogue). Second we have external dialogue (interactions in learning). External dialogue can be role specific (e.g. coaching a learner), or non-role specific (e.g. keeping the flow of conversation going). External dialogue is with other agents (e.g. tutor, computers, or other students) and plays a crucial role in learning.

The Du Boulay split outlined above raises an interesting question: what is the link between cognition and interaction in learning? Brown has considered the role of the 'supportive other' or 'agent of change' (e.g. teacher, mother, master craftsmen and craftswomen) in the context of interaction, cognition and metacognition. Brown (1987) has proposed that

> "the agent of change [is] responsible for structuring the child's environment in such a way that he or she will experience a judicious mix of compatible and conflicting experiences. The importance of such interactive learning experiences for general cognitive development should not be overlooked. Many cognitive activities are experienced in social settings, in time, the results of such experiences become internalized. Initially the supportive other acts as the interrogator, leading the child to more powerful rules and generalizations. The interrogative, regulatory role, however, becomes internalized during the process of development, and children become able to fulfil some of these functions for themselves through self-regulation and self-interrogation. Mature thinkers are those who provide conflict trials for themselves, practice thought experiments, question their own basic assumptions, provide counterexamples to their own rules,

etc. ... In other words, the child [or adult] learns how to learn." (Brown , 1987, p. 108)

Note that 'interrogator' above means questioning type interactions, e.g. as in Socratic dialogue (Collins and Stevens, 1991). The links that Brown makes are between interactions aimed at metacognitive development and the transplanting of the role of 'agent of change' from an external agent (teacher) to that of internal (to the learner) cognitive and metacognitive processes. These are very closely related to the Vygotskian concepts of mediation and internalisation (see Table 2.2 for definitions of these concepts). The concepts of interaction and metacognition are relevant to the 'Knowledge Mentoring framework', which is described in Chapter 3, where interaction and dialogue are seen as key ingredients for the promotion of creative reflection (i.e. metacognition) and learner autonomy.

2.2.1.3 Knowledge-of cognition and regulation-of cognition

Brown (1987) has made the following crucial distinction about metacognition, which other researchers still draw upon: metacognitive knowledge-of (i.e. what one knows about cognition, mental experimentation with ones own thoughts, the ability to imagine possible worlds); and metacognitive regulation-of processes (i.e. how one uses that knowledge to regulate cognition). Using an extension of this distinction, provided by Adey and Shayer (1994, p. 70-71), we can say that: (i) knowledge-of cognition refers to what individuals know about their own cognition, but that it can also involve a subprocess of *going-beyond* the present learning behaviour; and that (ii) regulation-of cognition is like *going-above,* as it were, and looking down on one's own thinking, an internal, 'conscious reflective awareness about strategies' and 'thinking about-thinking (and action)'. (Adey and Shayer, 1994, p. 71)

The subprocesses involved in knowledge-of cognition and regulation-of cognition are now considered. Knowledge-of cognition

"refers to what individuals know about their own cognition or about cognition in general. It usually includes three different kinds of metacognitive awareness: declarative, procedural, and conditional." (Schraw and Moshman, 1995, p. 352)

Declarative knowledge involves knowing about things. This includes knowledge about oneself as a learner and about what factors influence ones performance (e.g. "I'm not very good at sitting exams"). Procedural knowledge on the other hand involves knowing how to do things. This refers to knowledge about the execution of procedural skills (e.g. the steps involved in accessing the World Wide Web to perform an information search or playing a major scale on the piano). Conditional knowledge refers to the why and when aspects of cognition. This may be thought of as declarative knowledge about the relative utility of cognitive procedures (e.g. If I want up-to-date information I could use the World Wide Web, but if I want 'reliable' information a journal may be more appropriate).

'Going-beyond' refers to the what-if aspect of cognition. This is where a creative opportunity is imagined or a conversation is held with a tutor about a some problem that is currently being solved. Unless learners have recently gone beyond, they do not have anything to go above (i.e. to regulate) (Adey and Shayer, 1994, p. 70). The definition of 'creative reflection', presented in Chapter 1, has aspects of going beyond. To recap, creative reflection is defined as the ability of a learner to imagine opportunities in novel situations (going-beyond) and to then make accurate predictions about these opportunities (regulation).

Many studies (see Schraw and Moshman, 1995) support the claim that skilled learners possess declarative, procedural, and conditional knowledge about cognition (i.e., metacognitive knowledge of cognition). This knowledge usually improves performance. Although metacognitive knowledge need not be statable to be useful, conscious access to such information nevertheless may facilitate thinking and self-regulation (we will return to this point below when we discuss the self-explanation effect).

Regulation-of cognition

"refers to metacognitive activities that help control one's thinking or learning. Although a number of regulatory skills have been described in the literature, three essential skills are included in all accounts: planning, monitoring, and evaluation ...". (Schraw and Moshman, 1995, p. 354).

Planning involves the selection of appropriate strategies and the allocation of resources that affect performance (definitions for 'planning and 'strategy' are given in Table 2.1). Examples of planning include making predictions before reading or before hearing a musical phrase just composed played back, strategy sequencing, and allocating time or attention selectively before beginning a task. Monitoring refers to one's on-line awareness of comprehension and task performance. The ability to engage in periodic self-testing while learning is a good example. Several recent studies have found a link between metacognitive knowledge and monitoring activity. For example, Schraw (1994) found that adults' ability to estimate how well they would understand a passage prior to reading was related to monitoring accuracy on a post-reading comprehension test. Studies also suggest (see Schraw and Moshman, 1995) that monitoring ability improves with training and practice. Evaluation refers to appraising the products and regulatory processes of one's learning. Typical examples include re-evaluating one's goals and conclusions. With respect to text revision, one study (described in Schraw, 1994) found that poor writers were less able than good writers to adopt the reader's perspective and had more difficulty "diagnosing" text problems and correcting them.

Schraw and Moshman (1995) provide a useful conclusion on regulation:

"Researchers agree that regulatory competence improves performance in a number of ways, including better use of cognitive resources such as attention, better use of strategies, and a greater awareness of comprehension breakdowns. A number of studies report significant improvement in learning when regulatory skills are included as part of classroom instruction ...".

"[However] ... regulatory processes ... may not be conscious or statable in many learning situations. One reason is that many of these processes are highly automated, at least amongst adults. A second reason is that some of these processes have developed without any conscious reflection and therefore are difficult to report to others. A number of empirical studies support this assumption." (Schraw and Moshman, 1995, pp. 355-356)

Knowledge and regulation are inevitably closely interlinked. Schraw (1994) found that college students' judgements of their ability to monitor their reading comprehension was related to their observed monitoring accuracy. To a certain extent there is some overlap between monitoring and metacognition. The subprocesses going-beyond (knowledge-of cognition) and 'predictions' (regulation-of cognition) also appear to be closely related.

2.2.1.4 Self-explanations

In what has become a 'classic' paper in the field of cognitive science (i.e. at the top of the citation index for many years), Chi et al. (1989) have addressed the issue of statable metacognitive knowledge in the form of 'self-explanations'. Getting a learner to generate self-explanations can be considered as an important learning strategy that assists the integration of new knowledge with already existing knowledge. Self-explanations also allows the learner to build up a better and more complete model of the topic under study.

Chi et al. (1989) found significant individual differences in the kind of strategies and self-monitoring (regulation-of cognition) that students use to explain instructional text and examples to themselves. Their research investigated the metacognitive aspects of learning in physics (mechanics) and found that 'good' learners generate a large number of self-explanations and were able to accurately monitor their own understanding and misunderstanding. Thus it appears that students are not equally able to study instruction effectively (learning strategies), and may differ in their metacognitive abilities.

Most of the research in self-explanations has tended to be done in procedural domains like Physics. In a more recent study Chi et al. (1994) chose a more declarative domain, that of circulatory systems in biology. Students (eighth grade) were regularly prompted by the experimenter to self-explain during a task. The results claimed to show that prompting induced more self-explanations, and that these enhanced both learning and understanding.

However, in what was an interesting null result, Barnard and Sandberg (1996) report that in a series of studies aimed at teaching a declarative domain with a computer tutor, they found that most students do not spontaneously generate self-explanations, and even when and where they do, they do not necessarily have a positive effect on learning outcomes. The apparent difference between the Chi et al.'s findings and the research by Barnard and Sandberg can not be easily explained. However, one major difference between the two studies was that in the Chi et al. study, the self-explanations were prompted by a human experimenter.

Although somewhat dated now, a paper by Brown (1987) is still a key reference. Brown's discussion of the metacognition literature ranges through four main areas: (a) verbal reports as data (self-knowledge of cognitive processes), (b) executive control within an information processing framework, (c) self-regulation and abstracted reflection within the Piagetian framework, and (d) the Vygotskian notion of other-regulation. In our thesis we have drawn on aspects of reflective access discussed in (a), and the general notion that thinking is socially mediated by interaction with others (d). Readers interested in more detail on these aspects of metacognition are referred to this paper.

2.2.1.5 Critical thinking

Critical thinking relates closely to the perspectives on metacognition and self-explanations reported above. The approach taken, in our thesis, to critical thinking is not typical of the traditionally accepted philosophical view. However, it is fair to say that the traditions in the critical thinking movement are in turmoil as there seems now to be no agreement within the movement on a definition of critical thinking. Burrows (1989) has pointed out that approaches to critical thinking fall into three main areas of the philosophical, psychological and educational:

> "Although the professional clusters are not entirely clear cut, philosophers (philosophy of education included) seem to endorse argument analysis exclusively as critical thinking.

Psychologists lean towards critical thinking as a whole set of processes and skills, which argument analysis and problem solving exercises are necessary to improve, but not sufficient. The educators are inconclusive, but lean towards a definition incorporating the ideas of Dewey's essay How We Think, or reflective inquiry." (Burrows, 1989)

As Burrows points out above, critical thinking has traditionally been viewed from the philosophical perspective of logic and argumentation (for example Walton, 1989), where arguments are viewed as the representatives of internal belief-formation processes. However, there is debate that concerns the existence of a correlation between the public aspects of arguments, and internal reasoning processes. The second view of critical thinking is held by the psychologists, who combine problem solving with argument analysis. For example, Sternberg's (1985) definition of critical thinking requires the breaking down of intelligence into processes (there is disagreement as to whether there exists in the mind a general critical thinking capacity). Once they are understood, the strategic use of such processes in a particular situation is critical thinking:

"These processes may be divided into three types. *Metacomponents* are higher-order or executive processes we use to plan and monitor what we are going to do, and also to evaluate what we have done; deciding on a strategy for solving an arithmetic problem is an example. Whereas metacomponents decide what to do, *performance components* actually do it; the actual steps we use in solving an arithmetic problem are an example. *Knowledge-acquisition components* are used in learning new material, e.g. in first learning how to solve a given type of arithmetic problem." (Sternberg, 1985, p. 21)

Sternberg has given a full framework recently (Sternberg, 1994) that incorporates the above concepts. The third approach to critical thinking is where most educators fit. There is a serious lack of agreement about critical thinking among them (Burrows, 1989). Dewey's work on 'reflective inquiry' (Dewey, 1933) is often cited as the last word in critical thinking by many educators, and has been summarised by Skilbeck:

"'Primary experience' is both the starting point and the end point of inquiry; inquiry is critical, reflective, a knowledge-yielding process; and this reflective process is what Dewey means by secondary experience. Dewey wrote much about the process of inquiry leading to knowledge, than he did about primary experience. Even when discussing art ... he had little to say about the content of experience as 'primary'. Like Kant, he believed the mind plays an active part in the determination of the character of its own experiences: it undergoes, but it powerfully reacts on the world and seeks to order the effects of the world on itself ...". (Skilbeck, 1970, p. 14)

The approach to critical thinking taken in this thesis is based around the work of Lipman (1991). This approach is part of what has been termed the teaching thinking movement (Maclure and Davies, 1991), which tends to straddle all three approaches to critical thinking identified above. Indeed, Sternberg (1985) reviews three approaches that he sees as being able to teach his three components of critical thinking (see above); one of these is Lipman's Philosophy for Children (PC):

"Although limited somewhat by the range of students for whom it is appropriate, no program I am aware of is more likely to teach durable, transferable skills that PC." (Sternberg, 1985, p. 23)

Lipman (1991) has proposed that we must stipulate that education should include reasoning and judgement about knowledge. Education in the Lipman sense of the word is not 'simply' learning, it is a Vygotskian-like teacher-guided community of inquiry that places an emphasis on social interaction and cooperative learning. Lipman calls this 'the reflective model of education practice'. This educational theory is compatible with the objective of ILEs (described in Section 1.3.3), which emphasise the need for teacher mediated reflection about problem solving through dialogue. Lipman's reflective model of education practice has been used as a guiding educational theory for the framework that is described in the next chapter.

Furthermore, the critical thinking goal in our framework (described in the next chapter) if taken with the metacognition goal, falls into line with the three components of critical thinking identified above by Sternberg. We claim that the successful identification in our thesis research of the interventions and responses used by a mentor to engender critical thinking are a contribution in that they clarify what intervention the mentor tends to make and the response to expect from a learner. However, much AI-ED work into critical thinking has tended to look into argumentation, which has its roots in a philosophical tradition.

2.2.1.6 Mentoring

The term 'mentoring' can mean anything from a classical conception of a 1-to-1, highly idealised relationship to a conception where the mentor aims to provide either a role model or in-depth guidance (Freedman, 1993). The word 'mentor' first appeared as a character's name in Homer's *The Odyssey,* where 'Mentor' represented the embodiment of wisdom and acted as a guardian of the young Telemachus. In a formal learning situation, "mentoring functions can be understood as variously providing *support, challenge,* and *vision.*" (Daloz, 1990, p. 223). Furthermore, in the business world mentoring plays an important part in helping young aspirants to scramble up the corporate ladder. In sports, academia, music and the arts, mentors have long played a central role (even if they were sometimes called a coach). The notion of 1-to-1 tutoring by a mentor has been common practice in music composition teaching since medieval times. In education mentorship has often been used to refer to a faculty member who has a formal role than does a mentor in, say, business. The mentor can be an academic advisor, an independent study tutor, or a counsellor who teaches the student as well. Daloz (1990) has summarised the educational origins and features of mentoring as follows:

> "The role was pioneered in the 1950s by Goddard College and was later modified by such institutions as Empire State College and the Fielding Institute. While responsible for conveying a certain amount of academic content, mentors of this ilk tend to value their subject matter as much for its part in enhancing the overall intellectual and ethical development of their students as for its intrinsic worth. They are committed to promoting such generic abilities as critical thinking, the

capacity for empathy, the power to take diverse perspectives, and the will take positive action in a tentative world ... Their work is to empower their students by helping to draw out and give form to what their students already know. They call out the best parts of their students. They serve as midwives or guides rather than solely as sources of knowledge." (Daloz, 1990, p. 206)

The mentor supports the student in a developmental shift from a passive receiver of knowledge towards a more "critically reflective stance on their culture and a more active notion of themselves as a learner" (Daloz, 1990, p. 206). Thus, the mentor combines into one term some of the higher-order thinking notions in learning that have been discussed above:

- The 'agent of change' discussed in Section 2.2.1.2 links into the approach where the learner takes a more "reflective stance" through mentor guidance. Interactions would be aimed at metacognitive development and the transplanting of the role of 'agent of change' from an external agent (mentor) to that of internal (to the learner) cognitive and metacognitive processes.
- The self-explanations work described in Section 2.2.1.4 links in with the idea that the student take a "more active notion of themselves as a learner". Getting a learner to generate self-explanations can be considered as an important learning strategy that assists the integration of new knowledge with already existing knowledge. The learner is encouraged to regulate their own learning.
- The notion of a mentor also links in with Lipman's (1991) concept of a teacher led community of inquiry described in Section 2.2.1.5. Lipman (1991) has proposed that we must stipulate that education should include reasoning and judgement about knowledge (i.e. critical thinking).

As we will see in the next chapter, we have expanded the term mentoring in this thesis to include goals of promoting creative, metacognitive and critical learning.

2.2.1.7 *Conclusion*

The detailed investigation of the literature on reflective learning and teaching in musical composition, presented above in Section 2.1, has revealed that to date, relatively little research has been carried out in this area. As this review has shown, a growing body of research has started to address the nature of the link between teaching and students' higher-order reflections about their own learning, whether the term used is metacognition or critical thinking. However, a drawback with the research reviewed above is that it does not describe the processes involved in teaching and reflection about learning at the level of detail required to build a teaching agent in the problem-seeking domain of musical composition. This assessment of existing work provided part of the motivation for the empirical work described later (Chapter 5).

2.2.2 Computer-based systems for supporting higher-order thinking

Computer-based systems whose educational objectives include the aim of promoting higher-order thinking in a learner can be divided into two broad categories depending on the amount of learner control provided to the student. These are Learning Environments (LE) and Intelligent Learning Environments (ILE)[13]. There is probably a third category, in that some Intelligent Tutoring Systems (ITSs) have reflection as an objective (e.g. Katz and Lesgold, 1993), but a discussion of the latter category is beyond the scope of this thesis (in any case, ITSs tend to focus on promoting reflection on domain knowledge and not on meta-level knowledge). Table 2.2 shows a selective summary of systems that aim to promote higher-order thinking and identifies key issues that they raise. These systems are discussed below.

[13]MetaMuse, described in Chapter 6, would fit into the category of ILE because it is more concerned with managing the educational process and promoting reflection.

Table 2.2.

Selective summary of systems that aim to promote higher-order thinking

System	Domain	Reflective support	Issue
AlgebraLand (Foss, 1987) (LE)	Basic algebra.	Trace of student's solution path.	Reflective support was rarely used.
Explanation Environment (Recker and Pirolli, 1992) (LE)	LISP programming.	'Metacognitive' hypertext options, e.g. define your own conception of a 'New Word'	Reflective support largely ignored by experimental subjects
Simulation using STELLA (Pilkington and Parker-Jones, 1996) (LE)	Regulation of calcium by the human body.	Interactions with experimenter.	Inquiry dialogues may be a significant factor in prompting conceptual change.
MEMOLAB (Borcic, Dillenbourg et al., 1992) (ILE)	Experimental psychology skills.	Mainly neo-Piagetian orientation.	Attempts to merge discovery learning with different levels of teaching.
TAPS Project (Derry, 1992) (ILE)	Arithmetic story problem.	Vygotskian approach: student is cognitive apprentice, system cooperative mentor.	Complexity is a major problem in employing the apprenticeship model.
SCILAB (Hartley and Ravenscroft, 1993) (ILE)	Concept learning in science.	Vygotskian approach.	Learner reflection requires dialogue with a teacher.
Self-Explanation Coach (Conati, Larkin et al., 1997) (ILE)	Problem-solving performance in university-level physics.	Icon appears to remind students to generate self-explanations. Students are also given access to the problem solving/planning rules.	Focused on procedural domain level goals.

(Key: LE = Learning Environment, ILE = Intelligent Learning Environment.)

The first category, Learning Environments (e.g. simulations and hypermedia), makes the assumption that students possess the appropriate motivation, strategies, and self-monitoring (self-regulation) skills to control their own learning by exploration effectively. However, there are reasons to question some of these assumption. First, research (Foss, 1987; Recker and Pirolli, 1992) has shown that students may not be motivated to reflect in the manner intended by the system designers (see Table 2.2 for a summary). Second, Chi et al. (1989) have found significant individual differences in the kind of strategies and self-monitoring that students use to explain instructional text and examples to themselves (albeit with the assistance of strong experimenter prompting). As described above, their research investigated the 'metacognitive' aspects of learning in physics and found that 'good' learners generate a large number of self-explanations and were able to accurately monitor their own understanding and misunderstanding. Thus, it appears that students are not equally able to study instruction effectively (learning strategies), and may differ in their reflective and monitoring abilities.

Finding ways to motivate learner reflection appears to be a key issue for Learning Environments. Foss (1987) outlines experiments with AlgebraLand, an experimental Learning Environment that provides a small set of operators ('add', 'combine-term', etc.) for problem solving. AlgebraLand provides a trace of the student's solution path which students are supposed to reflect upon. However, in practice they rarely did this unless some further activity was devised to encourage reflection. A recent trend towards extending Learning Environments to include some form of 'explanation' has been partially motivated by a desire to make use of research in educational psychology (e.g. Chi, Bassok et al., 1989). A second example of how students may not be motivated to reflect about their own learning is provided by Recker and Pirolli (1992). They describe the design and evaluation of a hypertext-based Explanation Environment that utilises the results of the self-explanation research outlined above (Chi, Bassok et al., 1989) for programming new concepts in LISP. However, like AlgebraLand, the reflective support or 'metacognitive' features provided by Explanation Environment were largely ignored by experimental subjects.

Pilkington and Parker-Jones (1996) make a link between Vygotskyian-dialogue and the self-explanation literature that is similar to the approach being explored in this thesis. Pilkington and Parker-Jones use the instructional domain of medical students interacting with a simulation of calcium homeostasis. The main learning goals were to develop conceptual understanding and diagnostic reasoning skills. Pilkington and Parker-Jones also use a mark-up language to analyse interactions that is, in part, based on Self's (1993) DORMORBILE. However, there the similarities with our own approach ends (our own approach also draws on Self's framework). Pilkington's approach, called DISCOUNT, is based on an attempt to synthesise and extend existing approaches to discourse analysis including transactional analysis, dialogue game theory and rhetorical structure theory. Our own approach (the KMf is described in the next chapter) is based on speech and communicative act theory (these theories explained in Section 2.3.1). However, Pilkington and Parker-Jones's work is relevant to our own work because they found that inquiry dialogues may be a significant factor in prompting conceptual change. The implication from Pilkington's work is that students need to be given strategies on the best way to interact with peers and tutor, and that some form of inquiry approach may be better at promoting reflection and conceptual change.

The second category of systems aimed at promoting higher-order thinking is that of Intelligent Learning Environments. These aim to manage the education process interactively by engaging individual learners in some goal-directed, problem solving activity. Intelligent Learning Environments (ILEs) have tended to implement aspects of prominent theories that embed 'metacognition' (see the 'Reflective Support' column in Table 2.2 for a summary). For example, the MEMOLAB system (Borcic, Dillenbourg et al., 1992) is an ILE for acquiring basic skills in experimental psychology that opts for a mainly neo-Piagetian, constructivist, discovery learning orientation of reflection[14]. SCILAB (Hartley and Ravenscroft, 1993) is a design for an ILE that adopts a Vygotskian approach to concept learning in science. As we pointed out in Chapter 1 (and above in the context of Pilkington's work), the SCILAB researchers have concluded from their earlier work with computers and conceptual change in science that "self-reflection, or even reflective discussion between students may not be effective in changing beliefs and their 'organisation' into a conception" and suggest that this "requires dialogue with a teacher." (Hartley and Ravenscroft, 1993). SCILAB, therefore, aims to reason about learners' beliefs in

[14] Interested readers are referred to the paper by Brown, 1987, for a discussion of Piaget's reflected abstraction.

order to support interventions that promote reflection and which in turn support learner belief change and conceptual change.

The TAPS Project (Derry, 1992) has attempted to build a system for promoting metacognition based in part on 'cognitive task analysis' of performance in the domain. TAPS, which tackled the arithmetic story problem, is another system that uses a Vygotskian (Vygotsky, 1962) approach where the student is a cognitive apprentice and the system takes on the role of a cooperative mentor. This work highlighted the fact that complexity of cognitive apprenticeship interactions is a major problem in employing the apprenticeship model.

Conati, Larkin et al. (1997) have presented a computational framework for improving learning from examples by supporting self-explanations (SE). The paper (Conati, Larkin et al., 1997) describes the researchers' goal of developing and testing a computer tutor called the SE Coach. The system is designed to elicit and guide explanation with the aim of improving problem-solving performance in university-level physics:

> "In particular, the SE Coach focuses on two kinds of explanation that have appeared useful in self-explanation experiments:
>
> (a) explaining step correctness using the domain theory (here Newtonian physics); and
>
> (b) explaining step utility by identifying what goal each step satisfies in the plan underlying the solution." (Conati, Larkin et al., 1997, p. 280)

In an attempt to monitor and guide the student in their attempts at generating self-explanations, the SE Coach provides a Workbench and a probabilistic Student Model. The Workbench "interactively presents examples, prompts self-explanations, and provides principled tools for building them." (Conati, Larkin et al., 1997, p. 280). The workbench does not process natural language input, instead using a device to monitor the content and time duration of a student's attention, along with an interface that reminds students to self-explain and provide raw materials for constructing self-explanation. The Workbench achieves attention monitoring and control by hiding elements of the example that a student may be working on. Depending on the position of the cursor over the screen, text and diagrams become invisible or visible. The claim is that this approach focuses learner attention on one element at a time and that it gives the system data on viewed items with corresponding times:

> "Low viewing time suggests that little self-explanation has occurred. Although high viewing time may reflect more extensive explanations, it may also reflect confusion due to lack of knowledge, or merely doing something else (such as talking to a friend). Thus viewing times are suggestive evidence for self-explanation ...". (Conati, Larkin et al., 1997, p. 280)

We will return to the issue of viewing time in the discussion (Section 5.4.2) of one of the results from our empirical work (i.e. the pause taxonomy).

In the SE Coach, an icon appears near uncovered examples to remind students to generate self-explanations of correctness and utility. To build a correct self-explanation, the student is given access to the problem solving and planning rules of the Andes tutoring system, which it is claimed provide a complete specification of the domain knowledge. Thus, once a learner clicks on the explain icon and selects the prompt to explain the correctness of an aspect of the example, the learner is then presented with a series of pop-up menus that can be used to select a "goal path" through Andes Planning-rule index. In the paper Conati et al. show a selection of options as follows: apply-Newton-law, choose-body-properties. However, this, and the other options provided by the SE Tutor, are focused on what Ng and Bereiter (1995) call task-completion goals. From the example given in the paper, it would appear that SE Coach is not being used to generate self-explanations at any higher levels (e.g. what Ng and Bereiter call instructional goals or the highest level of knowledge-building goals). Thus, the approach to self-explanation in the SE coach seems focused at procedural, domain level goals. By focusing on 'imagining opportunities' and 'accurate predictions' we would claim that the approach used in this thesis research is more focused on the higher-level instructional and knowledge-building goals.

A question that arises from the above review is this: is the research summarised in Table 2.2 able to provide us with an approach to designing a system for supporting musical composition learning? We will now address this question by examining which aspects of higher-order thinking the systems summarised in Table 2.2 seem to be encouraging. At the beginning of this century Dewey (cited in Baron, 1981) proposed that "reflective thinking" should be an educational goal and that this is a type of thinking that considers options and reasons before choosing a course of action or adopting a belief. Baron (1981) draws on Dewey's proposal and lists the following five phases of reflective, higher-order thinking (which is our summary of Baron's, 1981, pp. 294-301, discussions):

Problem recognition or finding the problem.

Second, *enumeration* of possibilities, i.e. listing all the possibilities before evaluating them.

Third, *reasoning* in terms of searching for, or recognition of, evidence bearing on the possibilities.

Fourth, *revision* and use of evidence.

Fifth, *evaluation* of the possibilities to decide whether more thinking is required.

Clearly, Baron's first stage is of particular interest to our own research because the first stage is what we call (in Chapter 1 and Section 2.1) problem-seeking. If we compare Baron's five phases with the systems summarised in Table 2.2, then we find that these systems concentrate on the latter phases of reflection, i.e. phases three to five (and possibly phase two) and omit phase one. Furthermore, the systems in Table 2.2 are still at the experimental stage. It is therefore difficult to extract principles for designing new systems from the examples identified in Table 2.2 since they vary so widely in terms of their methodology and theoretical approach, and because they omit the problem-seeking stage (Baron's stage 1). Unresolved issues that are emerging from research into systems for promoting higher-order thinking can be summarised by the following question: what constitutes an adequate methodology for designing and building computer-assisted reflective learning systems?

2.2.2.1 DORMORBILE

Self (1993) has proposed a multi-level, conceptual architecture that distinguishes four levels of agent knowledge for student modelling purposes. The architecture is called DORMORBILE (a DOmain Reasoning MOnitoring Reflection Basis for Intelligent Learning Environments) and has provided a useful starting point for the development of the Knowledge Mentoring framework described in Chapter 3. DORMORBILE has already been described in Chapter 1, and is now discussed here in detail because of its importance to this research. Self's four levels are: Domain, Reasoning, Monitoring and Reflection. In order to make the four levels more concrete, below we provide an example for each of the levels for a learner in the subject area of music composition (Chapter 1 has already presented a detailed discussion of these four levels in terms of an object-level and meta-level split):

- Domain (D) level facts , e.g. "this is what is meant by pentatonic scale ... etc.".
- Reasoning (R) level processes in the learner, e.g. "using a pentatonic scale in a blues".
- Monitoring (M) level goals in the learner could mean they are assessing their progress towards a task goal, e.g. "does a pentatonic scale work here?".
- Reflection (Ref) level activity in the learner, e.g. considering the question "if the pentatonic scale didn't work too well can I think of situations where it does work?".

The domain and reasoning levels are concerned with cognition, whereas the monitoring and reflection levels are concerned with metacognition. Self (1993) points out that

> "DORMORBILE is a conceptual architecture: it may not be implementable in any significant sense. However it is through implementation that we will aim to clarify the contents of and

interactions between the various components." (Self, 1993, p. 15)

Building a computational model of DORMORBILE would be a classic AI approach to exploring its relevance to learning (no claims would be made for the cognitive validity of DORMORBILE)[15]. Indeed, the research described in this thesis does not intend to implement the full DORMORBILE. Instead aspects of the architecture are used to evolve the Knowledge Mentoring framework (Chapter 3). DORMORBILE does, however, remain a useful contribution to Artificial Intelligence in Education research in that it provides a framework for assisting us in our understanding of the links between knowledge, cognition, metacognition and interaction in learning.

Furthermore, the teaching agent described in Chapter 6 of this thesis is responsible for mentoring or overseeing knowledge in a way envisaged by Self. Self (1993) explains that in DORMORBILE, a teacher who is encouraging a learner to generate self-explanations would be represented as follows:

> The teacher is ... not directly solving problems, nor in fact reflecting on problem solutions, but is engaging in a fifth level, OK(t), the teacher's 'overseeing knowledge'.

Basically, Self would add a fifth level to his architecture, on top of the four level teaching agent, which would be responsible for 'overseeing knowledge'. The fifth level seems to be required for non-content knowledge, i.e. overseeing the learner's learning. It is this aspect, the fifth level, that has been investigated through empirical study and agent implementation in this thesis.

2.3 Interaction analysis and related problems

Approaches to linking interaction analysis to system design are reviewed in the subsection below (2.3.2). First, however, we provide a review of the literature

[15]However, it would appear that no implementation of any aspect of DORMORBILE has taken place: "In short, there is no 'implementation of DORMORBILE' (that I know of, and I don't really think there could be) which you could get hold of." (Self, personal communication, January 1997).

relating to speech acts, communicative acts, and goals, which form the theoretical basis to the approach to interaction analysis used in this thesis.

2.3.1 Speech acts, communicative acts and goals

A full review of the different approaches to interaction analysis is beyond the scope of this thesis, an emphasis is therefore placed in this section on the work that has stemmed form the Philosophical discipline (i.e. speech act theory)[16].

The KMf (which was summarised in Section 1.2 and which is described in detail in Chapter 3) draws on Speech Act theory, (Austin, 1962; Searle, 1969). In 'classical' speech act theory only invented isolated utterance are considered. More recently in speech act theory, dialogue is viewed as a sequence of speech acts, uttered by each party to achieve certain goals. Austin (1962) distinguished the locutionary act, the illocutionary act and the perlocutionary act. The locutionary act is the act of forming meaningful utterance from a language. The illocutionary act is the act of forming an utterance that can be interpreted as having intentional meaning representing the speaker's language goal. The perlocutionary act is the actual effect that the speaker's utterance has on the hearer, regardless of the speaker's intention. For example, when a crew member, of a submerged submarine full of drug smugglers that is attempting to evade a police patrol-boat, cries out: "If we don't get out of here soon we are all going to be caught!", the locutionary act (or force) of this warning may be to break the silence. The illocutionary act probably has the intention to give a warning, and a perlocutionary act may frighten the rest of the crew (this example is adapted from Winkels, 1992, p. 86).

Searle (1969) developed the idea of speech acts by attempting to establish the (felicity) conditions under which certain acts can be used (e.g. promising and requesting). Speech Act theory as developed by Searle has usually been taken to mean the illocutionary act: the performance of some speech action within a sentence indicating an act that the speaker makes in relation to another (e.g. an assertion or

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[16]Readers interested in an overview of the different approaches to the organisation and management of interaction are referred to Frohlich and Luff (1990, p. 194-199), who have drawn upon work by Kiss (1986) to provided a useful categorisation of approaches to dialogue analysis.

question). Speech acts are recognised by a hearer who will in turn make a speech act in response. A speech act has an intention behind it. Thus speech acts are applied to dialogue from the standpoint of a speaker's intention, and is often centred on the performative verb. However, as Petrie-Brown (1994) points out, one weakness of this approach is that it fails to model the changing goals of the interactants over several utterances:

"The major work on the speech act published by Searle (1969) and much of the subsequent work, does not see fit to look further than the intentions and effects of the illocutionary act. This is symptomatic of the emphasis on sentential analysis and non-interactive language research. When the changing goals and beliefs of the interactant are modelled over several utterance turns the sentential illocutionary act description becomes an inadequate account of the interactants' ... intentions and actions. To look at the perlocutionary act and intentions requires that the scope of the analysis be greater than the recognition of 'surface' speech acts." (Petrie-Brown, 1994, pp. 45-46)

Searle went on to develop a taxonomy of illocutionary acts (Searle, 1976) in which he classified all speech acts as embodying one of five fundamental illocutionary points, which are, paraphrasing Searle (1976, pp. 10-16):

Representative (or assertives). Commit the speaker (in varying degrees) to something's being the case, to the truth of the expressed proposition.

Directives. Attempts (of varying degrees) by the speaker to get the hearer to do something. These include questions (which can direct the hearer to make an assertive speech act in response) and commands (which invite the hearer to perform some interaction).

Commissives. Commit the speaker (again, in varying degrees) to some future course of action.

Expressives. This class express the psychological state specified in the sincerity condition about a state of affairs specified in the propositional content. Examples include acts such as apologising and praising.

Declarations. Bring about a correspondence between the propositional content and reality. An example of this act would be if I successfully perform the act of marrying you, then you are married.

The illocutionary point specifies meaning in terms of patterns of commitment entered into by speaker and hearer in an interaction. Thus, Searl's taxonomy classifies the possibilities for what a speaker can do within the context of an utterance. For Searle, the illocutionary force of an utterance is different from its illocutionary point (the latter being one of the above five categories) and its propositional content. Two speech acts (such as a polite question and a confrontational demand for information) may differ in their illocutionary force (manner and degree) while having the same illocutionary point (in the example both acts are directives). Propositional content is a fact, or a proposition about some topic, included in an utterance, e.g. "register is the range of a human voice or of a musical instrument".

Since speech acts have limitations beyond those described above by Petrie-Brown, 'communicative acts' have been used by Baker (1994) to extend their applicability:

> "Existing AI work on modelling the mental states underlying agents' recognition and generation of speech acts (see, for example, Cohen, Morgan et al., 1990) has generally relied on invented idealised utterances, and the utterance types that have been most studied are different kinds of assertions, questions and requests. In this paper we shall attempt to show that when we approach the study of real teaching-learning dialogues with these theoretical tools, new types of communicative acts need to be considered and defined, and existing modelling approaches need to be modified in order to plausibly account for the data. This is one way in which AI&Ed research on dialogue analysis can contribute to AI in general." (Baker, 1994, p. 204)

Baker (1994) describes a model for negotiation, based on analyses of teacher-student and learner-learner interactions. Baker argues that the propositional attitude most relevant to negotiation dialogues is acceptance rather than belief (acceptance is a commissive illocutionary point in Searl's taxonomy, described above). Baker (1994) proposes a model for negotiation as a process that is based on communicative acts and a set of different types of relations between offered propositions:

> "We adopt a specific speech act theoretic approach called "communicative act" (CA) ... theory. This approach has its problems ... but we believe that it can be extended to meet objections, and that it can provide comprehensive coverage of most communicational phenomena. According to CA theory (Gazdar, 1981; Bunt, 1989), communicative acts are *functions from contexts into context,* where a context is the union of epistemic states of dialogue agents - for example, "... an assertion that 'ø' is a function that changes a context in which the speaker is not committed to justifiable true belief in ø into a context in which he is so committed" (Gazdar, 1981, pp. 68-69). This circumvents a number of well-known problems in speech-act theory, such as the lack of a simple one-to-one relation between sentence form and illocutionary force (assertions do not always have to be declarative, nor questions always interrogative sentence forms). Communicative acts are therefore to be identified with their appropriateness conditions (Searle, 1969) and their context-changing effects. Thus what counts as a "question," "inform," "request," etc., does not depend directly on the linguistic form of utterances, but ... [on] any communicative means ... which evaluates the corresponding function. Communicative acts are therefore conventional, "packages" of epistemic states which may be communicated in dialogue; communicative functions ("CFs") are names for the immediate or direct ... effects that occur when these packages are communicated. Single utterances may realise different communicative functions in different context, or multiple simultaneous functions in the same context." (Baker, 1994, pp. 223-224)

For Baker, the common goal of negotiation is to reach an agreement where (i) negotiating agents may have individual and competing goals, (ii) negotiations consist basically of sequences of offers that may be accepted or rejected, and (iii) two possible negotiation strategies are to refine the original offer towards agreement, or to keep an offer fixed and to attempt to persuade the other to accept by argumentation (the latter strategy places Baker's approach to critical thinking in the philosophical tradition reviewed above in Section 2.2.1).

In her study of human dialogues, Fox (1993) proposes a some rules for negotiation:

> "As tutor and student work together to arrive at an approach to the session, the tutors variously offer suggestions for how to proceed, modify, transform, or accept suggestions from the student. A rough analysis of the negotiation looks something like this: If the tutor accepts the student's approach, then the tutor and student set about getting "to work"; if the tutor modifies or transforms the student's suggestion, or makes the original suggestion, then the student can accept, modify, transform, or reject the tutor's contribution. If the student modifies or transforms the tutor's suggestion, the process recycles, with the tutor accepting or modifying the student's emendation, and the student can now either accept or modify the tutor's contribution. This process could in principle continue indefinitely, but in none of our sessions did we see more than a few rounds." (Fox, 1993, p. 36)

Negotiation is a highly collaborative process, making it difficult to assign a suggestion to just one of the participants. Fox's approach to negotiation is of interest because it provides some detail of the mechanisms involved in interactive learning on a 'minute-by-minute' basis. However, Fox's work is not as formally specified as the approach put forward by Baker (1994). Neither approach makes an explicit link between an agent's internal goals and the interaction that may result from the agent carrying out actions at the communicative act level to achieve these goals (although Baker would take such a link to be a desirable one).

Power (1979) was amongst the first to discuss the relationship between goals, planning and communicative actions in purposeful dialogues. Power introduced the idea of a shared goal tree, where the responsibility for various nodes is either shared or distributed between two agents engaging in dialogue relating to the joint solution of a problem. Power also emphasised the goal-directed nature of speech acts:

> "The general form of my solution is this: the utterance X is regarded as a goal in the speaker's

mind, and this goal is related to the higher goal G by a planning tree which specifies the intermediate goals ... My account therefore has the advantage that it relates speech acts to those non-speech acts with which they have an affinity." (Power, 1979, p. 140-144)

Kiss (1986) has elaborated on the goal directed-nature of interactions in his work on high-level dialogue. High-level dialogue is concerned with the overall goal structure of interactions rather than the detailed structure of a communicative act. Specifically, the term high-level dialogue refers to linguistic and non-linguistic communication that occurs between rational agents pursuing overlapping sets of goals in a task domain:

"Task oriented dialogue between rational agents is not confined to commands but can make use of *a variety of communicative acts* like assertions, questions permissions, prohibitions, obligations, requests, etc. Much of a dialogue is concerned with the clarification of goals and with negotiations about responsibility for them, in addition to instructions for direct action ... The support for *cooperative interaction* between user and machine is the essence of high-level dialogue." (Kiss, 1986, p. 1).

The work by Kiss and Power on high-level dialogue complement Baker's work on communicative acts (CAs) and communicative functions (CFs) in that taken together, this body of work provides the theoretical basis for linking speech acts to the goals of interactants over a period of time (this is in fact what our own approach, the KMf, attempts to achieve). Furthermore, Kiss has also elaborated on the notion of higher-level dialogue in open-ended domains as follows:

"In general, the more open-ended the task the user is trying to tackle, the more it will be necessary to provide aspects of high-level dialogue at least in the form of advice if not by the execution of autonomous action on the user's behalf." (Kiss, 1986, p. 20)

High-level dialogues are thus appropriate to the open-ended, problem-seeking domain of music composition, where (as we argued in Chapter 1) there is often no single correct solution to a musical composition problem. In high-level dialogues in problem-seeking domains a teacher is not 'merely' intending to deliver content, the teacher has a goal of giving advice, coaching, or mentoring. The intention behind such an intervention is that the learner will accept the goals and carry out creative, metacognitive and critical thinking for themselves.

A classic approach to AI is to recognise that an agent carries out actions in order to satisfy goals. However, the AI literature has not arrived at a uniform meaning for the term 'goal'. Slade (1994) has provided the following definition which provides a useful starting point:

> "A goal is a state of the world which an agent explicitly desires to achieve, preserve, avoid, or destroy." (Slade, 1994, p. 49)

Slade presents fifteen features or dimensions that are useful for characterising goals. However, some of these dimensions (e.g. Slade's 'Values') are what can be termed in agent theoretic terms 'agent attitudes' (this point is explored in Section 2.4). For now, the simple definition of a goal given above suits our purpose and we refer readers to Slade (1994) for a useful discussion of the AI literature on goals. Vassileva (1997) has recently presented the design for a goal-based teaching agent that is based on Slade's taxonomy of goals. In our own work (Chapter 3) we develop a taxonomy and definitions of goals that relate to high-level dialogues and an agent model which includes agent theoretic concepts of belief, wants, intention, and commitment.

2.3.2 Linking interaction analysis to system design

Building systems that promote dialogue in learning interactions has long been a concern of ITS research. Over a quarter of a century ago Carbonell (1970) introduced the term 'mixed-initiative' in his SCHOLAR teaching system (cooperative interaction involving shared plan formation and execution). Clancy's (1979) GUIDON system paid considerable attention to implementing dialogue goals, which were achieved by rules governing discourse procedures. However, the idea that we can somehow base system design on a study of dialogues is a separate concern to building systems that promote dialogue (although the former may lead to the latter).

In Section 1.3.4 we pointed out that the WHY system (Stevens, Collins et al., 1982) provides an example of an early attempt to base system design on a study of human tutoring (albeit an informal approach). Woolf and co-workers (Woolf, Murray et al., 1988) have used Tutoring Action Transition Networks (TATNs) as a control tool for facilitating the specification and modification of prototypical patterns of tutorial behaviour. The tool is intended to be used for eliciting discourse patterns from domain experts whilst building an ITS for science education. Arcs (arrows) represent predicates which track the state of the dialogue (e.g. simple slip, incorrect answer). Nodes represent a tutor's action (or an entire network recursively invoked), e.g. teach by consequence or teach by example. Woolf et al. suggest that some of the networks are derived from empirical work. Unfortunately, one of the papers cited as the source of the empirical work is not available in a publication. This in turn prevents any realistic assessment of the way in which the empirical dialogue analysis work was used to inform the design of the networks.

Although the two examples mentioned in this thesis so far (i.e. WHY and Woolf et al.'s TATNs) are only meant to be illustrative, we suggest that, to the best of our knowledge, only a small body of research has examined how to systematically use empirical data, taken from dialogue analysis, to inform teaching agent design. In the EUROHELP project (Winkels, 1992, Section 6.2), empirical data from dialogue analysis was used to support many of the principles that guided the construction of a prescriptive model of coaching. However, the main use of the empirical data in the EUROHELP project was to provide a basis for comparison with a computer-based coach (called the Didactic Discourse Planner). Consequently, it will be argued that the research reported in this thesis has provided an original framework that allows for the systematic analysis of mentoring interactions and subsequent exploration of the way that empirical data that can be used to inform the design of a computer-based teaching agent.

The study that appears to come closest to our own work is the work by Blandford (1991), who used empirical work to design an agent to support and improve people's decision making in the domain of design evaluation in engineering. Blandford conducted a small-scale protocol study in order to inform the design of her teaching agent, which is called WOMBAT. One aim of the study conducted by Blandford was

> "to ascertain what notes subjects took during their decision making, and how they chose to structure and manipulate the information they used in their decision making; if a pattern emerged, then this would provide evidence to inform the design of a computer-based tool to support this activity." (Blandford, 1991, p. 66)

Thus, the analysis approach used by Blandford focused mainly on the task goals for that domain, and not the higher-level pedagogical goals. Part of the approach used by Blandford did give counts of instances, within the five dialogues analysed (each dialogue was between pairs collaborating on the solution to a problem), of "events" that interested Blandford (1991, p. 282), e.g. Disagreement, Meta-level and Refer to "too much data". However, Blandford does not make it clear how this data on dialogue events was used in the design of the teaching agent. The agent theory upon which WOMBAT is designed has, however, been used as the starting point for our own work (we return to this point in Section 2.4).

Winograd and Flores (1986, pp. 64) demonstrate an approach to representing networks of speech acts which they call 'conversations for action'. These state transition networks can form the basis for computer tools (Winograd, 1987-1988) and are thus a useful approach, which has been adapted in Chapter 5 to meet the analysis needs of our own research. The approach provides a formal representation of the interplay between speech-act illocutionary point (Searle, 1976) 'directives' and speech-act 'commissives' that are directed towards some explicit cooperative action. Winograd has pointed out that when applying these networks to computer system design:

"the concern is not with duplicating the knowledge or thought patterns of people, but with the structure of their interactions and the embedding of those interactions in computer systems." (Winograd, 1987-1988, p. 10)

This design concern falls in neatly with a recently proposed hypothesis by Sandberg and Andriessen (1997), namely:

"that the more options for interactivity the learning situation has to offer, the more learning that may occur ... Interactivity, taken as reciprocity in the learning process, is a core quality of new media, but in our view it is still poorly exploited. It is, on the one hand a function of adaptivity of the learning environment to the learner's needs, and on the other hand, the consequence of monitoring and control by the learner." (Sandberg and Andriessen, 1997, p. 548)

We would agree that interactivity is poorly exploited in learning environment design. Winograd (1987-1988) has, however, illustrated his approach to offering structure to interactions by describing a system called The Coordinator, a "first-generation conversational system" used in business. Like the SE Coach (described in Section 2.2.2), the Coordinator is menu driven. The Coordinator provides options for opening conversations that have different implicit structures of action. When, for example, a user selects 'Request' to open a conversation with another user, a template appears prompting the user to specify addressee and subject. The system then provides the following sentence opener: "what is your request", to which the user can enter any text whatsoever. The design issue underlying this functionality is described as follows:

"The system makes no attempt to interpret the text, relying on the user's understanding and cooperation that the message is properly identified as a request. This is a key design issue: Let people do the interpretation of natural language, and let the program deal with explicit declarations of structure (such as a user's that this is a request)." (Winograd, 1987-1988, p. 11)

Taking the Winograd design issue (embedding the structure of interactions in computer systems) and Sandberg's suggestion that interactivity is poorly exploited in the learning media, we can see that there is a tension. Winograd goes for menus as a way of structuring interactions. There are two main alternatives to the embedding the structure of interactions in the interface. First, a more formal description language could be adopted like that used in Blandford's WOMBAT system (Blandford, 1994), where the system designer has to act as an interpreter between the agent and subjects in evaluations of the system. Second, a full natural language understanding system could be used. The latter is still not a reality in that natural language understanding systems for problem-seeking interactions do not as yet exist. Furthermore, description languages are cumbersome in real learning situations. Both approaches are, however, promising lines of research. Although the Winograd approach has its critics, it represents a very useful design method, and one that allows us to analyse interaction data and abstract networks that can be used to structure interactions (Section 5.5 will elaborate on this point).

2.4 Teaching Agents

Teaching agents (or pedagogical agents or agent-based learning environments as they are sometimes called) are becoming a popular trend in AI-ED research. For example, AI-ED 97 (Du Boulay and Mizoguchi, 1997), a major conference in the field of AI-ED, had a workshop devoted to pedagogical agents. An example of successful, and large-scale, work in the area of pedagogical agents is provided by Lester, Converse et al. (1997). Lester's team conducted an empirical evaluation with 100 middle school students interacting with an animated pedagogical agent that gives advice in a learning environment for botanical anatomy and physiology. The agent is described as animated because it takes on the characteristics of a cartoon character. Lester, Converse et al.'s agent can behave autonomously to support learning. The study found that their agent can yield improved problem solving (particularly for complex problems). Several agents were used in the study, ranging from talkative agents to less expressive agents. Lester, Converse et al.'s study also found that the more expressive agents used in the study yielded greater improvements in problem solving.

An agent is understood in this thesis to be an integrated natural or AI system where, in "order to satisfy their values, agents derive goals from them and then form intentions to take action to reach these goals" (Kiss, Domingue et al., 1991). Specifically, in this thesis we draw upon the work of Kiss, Domingue et al. to define an agent as follows:

> "By taking action, agents actively attempt to satisfy a value system that describes what is desirable. In order to satisfy their values, agents derive goals from them and then form intentions to take action to reach these goals. The use of value systems produces systems with capability for autonomous (unsupervised) action because the inclusion of a value hierarchy ensures appropriate action over a wide range of situations. Agents know facts about their environment and about themselves. They communicate with each other by sending messages containing declarative facts, requests for action, declarations of values or goals, etc., which are all instances of communicative actions. The problem solving capabilities inherent in agents enables them to communicate requests very concisely and declaratively in terms of goals rather than procedural action sequences." (Kiss, Domingue et al., 1991. p. 2)

In the AI literature the term 'agent' is widely interpreted and many important issues remain unresolved. It is not the purpose of this section to provide a comprehensive review of agent theory as it applies to dialogue[17], nor to provide a review of pedagogical agents (interested readers are referred to the proceedings of the conference mentioned above). In this section we only review agent theory that is directly relevant to this thesis.

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[17]A review of this literature can be found in Chapter 5 of Blandford (1991).

2.4.1 Kiss' agent theoretic concepts

Kiss (1988) has proposed that an agent has three classes of attitude: cognitive, conative, and affective (hedonic). Kiss suggests that an agent architecture needs to support these different classes of attitudes in order to support the requirement for action (conative or epistemic class), re-action to the environment (cognitive or praxiological class) and autonomy (affective or axiological class):

> "Some of the attitudes, for example the epistemic ones, are regarded as components of the agent's state. Others, for example wants, are regarded as component processes within an agent. Attitudes are therefore functionally implemented (could also be said to be operationalised) through states and processes in a system ... The objects of the attitudes are the world states which the agent bears the appropriate relation ... In the case of the attitude of wanting I call the object of the attitude the *goal* of the want ... In my framework a goal is just a world state (which has state description) and the attitude is the want. A goal is thus a special case of being an object for an attitude, in the case of wants. Intentions also take as their objects some state, or rather state sequence, of the world, which happens to be an action of the agent. The state sequence can be described propositionally, as usual." (Kiss, 1988, p. 8)

The main cognitive attitudes in Kiss' framework are knowledge and belief. For non-attitudinal knowledge, an agent knows a proposition P, if whenever the agent is in state S, P can be asserted about the world. For knowledge as an attitude Kiss adds the requirement of a mechanism of iterated introspective knowledge, i.e. an agent takes an attitude of knowing a proposition if a subset of the components of the agent are in a state of common knowledge with respect to that proposition. Common knowledge is the situation when everyone knows that everyone knows ... that everyone knows ... that everyone knows a proposition (i.e. there is a theoretical requirement for infinite iteration). Beliefs are held to be true by a given agent. Kiss regards beliefs as uncertain knowledge, i.e. approximations to knowledge either because it has limited support (reasons) or limited introspective support.

The main conative attitudes are wants (an attitude towards some proposition or state) and intentions (an attitude towards an action, possibly specifying some commitment by the agent to carry out that action; the commitment may or may not be conditional):

"A want is the main type of attitude in the conative attitude class. It is directed at a situation, which is called the *goal.* The attitude of wanting is operationalised as a process directed towards the goal state. Inconsistent wants are allowed and are made use of by the theory. They are intra-agent *conflicts* and they get resolved in practical reasoning by making *choices.* The mechanism for making choices between wants is based on the intensities of wants. The intensity of a want is operationalised in terms of the resource allocations or demands made for the process of moving towards its goal ... An intention is the a [sic] state of an agent in which an action has been selected for execution, but execution has not yet begun, or, more generally, the assignment of a temporal priority to a 'want process'. Intentions can be conditional and may get executed only when the condition is satisfied." (Kiss, 1988, p. 9)

As we saw in Section 2.3.1, Baker (1994) argues that the propositional attitude most relevant to negotiation dialogues is acceptance (a conative attitude) rather than belief (a cognitive attitude).

Affective attitudes include pleasure, liking and value. Kiss argues that such attitudes are important, because autonomy in agents is vitally dependent on the presence of some mechanisms through which the agent is able to adopt its own goals. Agents can take attitudes, such as 'liking' and 'disliking', in situations in which hedonic states (not attitudes) occur. Such hedonic states can be produced in parts of the agent by both environmental and internal causal influences. The common terminology to label such states is pleasure and pain. Kiss summarises affective attitudes as follows:

"experience of pleasure causes attitudes of liking to be formed towards an actual ("here and now") situation. This is generalised to non-actual, but possible, situations, based on past experience. In this way a value is attached to possible situations. The agent may then decide to form a further attitude of wanting the possible situations, adopting them as goals, because he already has the attitude of valuing them." (Kiss, 1988, p. 11)

2.4.2 Blandford's WOMBAT teaching agent

Blandford (1991) has already proposed, implemented and evaluated a teaching agent based on Kiss' (1988) framework of attitudes. In Section 1.2.3 we described a computational model that draws on Blandford's work. Furthermore, in Chapter 6 we will describe how the code for Blandford's agent was adapted and extended for our own purposes. Consequently, we will spend some time in this section giving details of those aspects of Blandford's agent that were found to be particularly relevant to our own work. Blandford's work on focus spaces, transient goals and negotiated beliefs has not been adopted in our own work.

The dialogue component of Blandford's agent is capable of engaging in purposeful dialogues and collaborative problem solving, is capable of negotiating about what to do next and about what beliefs to take into account in problem solving. As Blandford (1991, p. 120) points out, the agent does not engage in planning (interaction is opportunistic) and it has fixed expertise in its domain of action (it cannot learn).

The attitudes included in Blandford's model are as follows: standard and mutual working beliefs (cognitive attitudes); plus wants, commitments and goals (which are conative attitudes, although goals refer to aspects of the state of the world, whereas wants refer to goals and commitments refer to actions). Wants refer to all known ways of achieving the goal, commitment refers to the chosen way of achieving goal by action. Blandford's model also includes the notion of a transient goal, which is a goal which an agent will address at some future time, or which the agent believes may take several attempts before it is achieved. The affective attitudes encoded in Blandford's agent model are values, which are encoded in an isolated preference mechanism, in which a choice is made between alternative possible actions.

Blandford's teaching agent's main values are hedonic (relating directly to the agent's pleasure) and pedagogical (concerned with aspects of teaching well, and therefore only indirectly contributing to an agent's pleasure). Blandford describes the mechanisms involved in her value component as follows:

"Values are located in the preference mechanism, and are therefore not accessible to the agent itself. They are only used for deciding between alternative possible actions. Located in the same place are means-ends beliefs about what values actions satisfy, and under what circumstances (i.e. when which aspect of the world state is true ... A consequence of locating values and means-ends beliefs within the preference mechanism is that the agent is not aware of these attitudes. For example, it cannot discuss them with a user." (Blandford, 1991, p. 126)

Blandford also draws on Kiss, Clark et. al's (1988, p. 34) notion of an action cycle:

"The core of the theoretical agent model is an action cycle which operates on a goal-action tree in order to make decisions and become committed to action. An agent's activity involves many iterations of the action cycle while traversing the goal-action tree." (Blandford, 1991, p. 126).

Figure 2.1 shows a flow diagram, taken from Blandford (1991, p. 129), defining sequence of choices and actions. Goals are in circles, addressing a goal involves choosing between possible actions (rectangles) and performing the chosen action. In Blandford's agent model the form of representation used to indicate the relationships between goals and actions is a tree structure (a modified and-or tree). The action cycle is therefore seen as tree traversal mechanism. For every goal in Blandford's trees there is at least one goal-reaching action. With the exception of goals that correspond to goal-reaching actions, the agent decides, through a preference mechanism, when a goal has been reached or should be dropped. Commitments are fulfilled through the reaching of sub-goals, and the agent can not explicitly decide to drop a commitment (except through deciding to drop the sub-goal). Actions a2, a3, a4, a5, a6 and a7 in Figure 2.1 are basic actions (which the agent can execute directly). Actions a1 involves reaching goals g2 and g3. Goal g2 is reached by performing action a4, and g3 by performing a5 any number of times, followed by either a6 or a7. Blandford admits herself (p. 129) that the distinction between goals and action can sometimes seem a little blurred. Perhaps a better representation would have been: goal, sub-goal 1 ... sub-goal x, action (where a sub-goal can perform some action). The problem appears to be that Blandford's goal-tree contains some very big primitive actions (e.g. 'make agreement specific', p. 169) which need further decomposing.

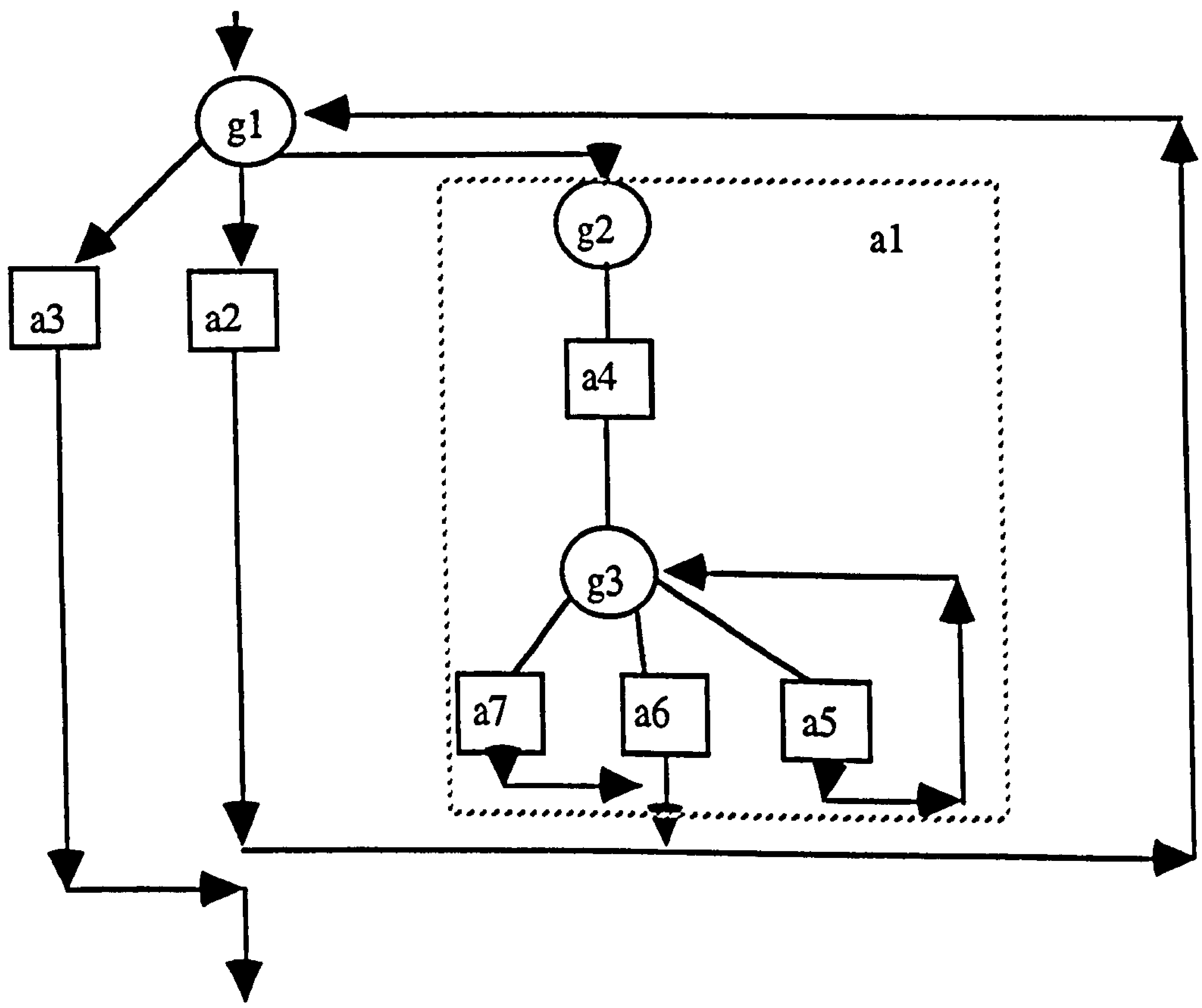

Figure 2.1. Example flow diagram (Blandford, 1991, p. 129).

Decisions are made by Blandford's agent in a preference mechanism, which works as follows:

"The preference mechanism is based on Multi-Attribute Utility Theory, referred to earlier as

Weighted Objectives Method ... For any goal which can be addressed by more than one action, there is a list of the possible actions. For each possible action, there is a list of means-ends beliefs about what values that action satisfies, and how well (as measured by a numerical strength) and under what conditions. Each value has a numerical weight attached to reflect its relative importance to the system." (Blandford, 1991, pp. 130)

Pedagogical values are built into the system as follows:

> "The computer-based agent has values which are relevant to its role as teacher. These values include values relating to the user externalising and reflecting on their beliefs, motivational values such as keeping the interaction varied and ensuring that the user does not get stuck, and hedonic values (i.e. values relating to pleasure) such as making as little effort as possible. These values, together with the ability to perform particular dialogue actions and means-ends beliefs about which values any given action satisfies, define the teaching style of the system." (Blandford, 1991, p. 139)

The pedagogical approach used by the WOMBAT agent draws on theory (e.g. theory relating to externalising and reflecting) and Blandford's intuitions (values are given a weighting in the preference mechanism, these numerical weightings are derived from Blandford's intuitions) in order to instantiate the teaching approach adopted by the agent. In a formative evaluation of the implemented agent (called WOMBAT), Blandford found that it was capable of engaging in a coherent dialogue, and that the dialogue was seen to have a pedagogical purpose. One small criticism of the evaluation design is that the questionnaire questions (sheets were filled in by subjects following a session with WOMBAT) are far form neutral. For example question 2 (Blandford, 1991, p. 339) is worded as follows: "The dialogue: was it quirky, sensible, helpful, useless, confusing flexible ...? Ignoring the strange sentence construction, did any of the system's utterances strike as surprising in any way? If so how?". This is really three questions rolled into one, plus the question ends with a very leading statement (this question seems to be leading the respondent into a particular reply about the surprising nature of an utterance).

Blandford's work did, however, make a useful contribution to AI-ED in that it attempted to implement a large number of agent theoretic concepts (e.g. Kiss'). It would appear that the agent theoretic concepts of Kiss and Blandford have not been further explored by the pedagogical agent community. The work described in Chapter 6 of this thesis attempts to build on some aspects of Blandford's work and to extend it.

2.5 Summary of the literature

This chapter examined the literature on musical composition, higher-order thinking, interaction analysis and teaching agents. The main points raised are now summarised below.

No consensus exists on how to teach musical composition. Similarly, in higher education in Britain and Ireland, there is no consensus on 'what' aspects of composition to teach. Some important musical processes have been reported in the literature on musical cognition. For example, Davidson and Welsh (1988) have suggested that the use of melodic motives is not only a powerful means of achieving structural unity and contrast, but their use by a composer also reflects the ability to think in larger structural chunks. Furthermore, evidence was found in the literature to support the notion of problem-seeking. In creative problem solving, the first stage is often to problem seek. The process of problem-seeking will involve a composer in an attempt to formulate or create the problem before a method for arriving at a solution can be identified.

One implication from the literature was that a composer needs a well developed memory and the ability to visualise and make predictions about the structure of a planned composition if they are to compose successfully (e.g. to think in larger structural chunks). Some research has found that some students in higher education may tend to let musical sequencer software tools do much of the work when composing and, consequently, do not develop visualisation and memory recall of composition structure abilities. Furthermore, it appears that no research has investigated how computers can be used to support musical composition and creative reflection in higher-education.

The above issues give rise to the following question: how do we learn how to build the memory structures that are required for successful composition? One approach (Auker, 1991) is to allow learners to develop the appropriate spoken language, which they can adapt and take ownership of as they begin to internalise and 'reflect' on creative opportunities, and hence build the appropriate mental structures of their creative intentions. A more precise definition of reflection is to call it metacognition. Metacognition can be defined as understanding of knowledge, an understanding that can be reflected in either effective use or overt description of the knowledge in question. However, the further question arises: what is the link between metacognition and interaction in learning? The link may be that interactions aimed at promoting metacognitive development in a learner should aim at the transplanting of the role of 'agent of change' from an external agent (e.g. the teacher mediating the 'appropriate spoken language') to that of internal (to the learner) cognitive and metacognitive processes.

The following crucial distinction about metacognition can be made: metacognitive knowledge-of (i.e. what one knows about cognition, mental experimentation with ones own thoughts, the ability to imagine possible worlds); and metacognitive regulation-of processes (i.e. how one uses that knowledge to regulate cognition). We can say that: (i) knowledge-of cognition refers to what individuals knows about their own cognition, but that it can also involve a subprocess of going-beyond the present learning behaviour (creative thinking); and that (ii) regulation-of cognition is like going-above and looking down on one's own thinking. In some respects the notion of creative, metacognitive and critical thinking tend to overlap. Critical thinking for Lipman (1991) includes reasoning and judgement about knowledge. Education in the Lipman sense of the word is not 'simply' learning, it is a Vygotskian-like teacher-guided community of inquiry that places an emphasis on social interaction and cooperative learning. The notion of 1-to-1 tutoring by a mentor has been common practice in music composition teaching since medieval times, thus making music composition the ideal starting point for examining creative, metacognitive and critical thinking in learning.

A drawback with the research on metacognitive and critical thinking is that it does not describe the processes involved in teaching and reflection about learning at the level of detail required to build a teaching agent in the problem-seeking domain of musical composition. Furthermore, a question that arises from an examination of computer-based systems that have an educational objective of promoting reflection is this: are these systems able to give us an approach to designing a system for supporting musical composition learning? The systems reported in the literature omit support for the problem-seeking phase of problem solving. Furthermore, many of these systems are still at the experimental stage, making it difficult to extract principles for designing new systems. Self's (1993) DORMORBILE architecture does, however, provide a useful framework for assisting us in our understanding of the links between knowledge, cognition, metacognition, interaction in learning and system design.

Speech Act theory, (Austin, 1962; Searle, 1969) is one approach to understanding the organisation and management of interactions. Recent speech act theory has come to view dialogue as a sequence of speech acts, uttered by each party to achieve certain goals. However, one weakness of this approach is that it fails to model the changing goals of the interactants over several utterances. Because speech acts have limitations beyond this, 'communicative acts' (Bunt, 1989) have been used by Baker (1994) to extend their applicability. Baker (1994) has proposed a model for negotiation as a process that is based on communicative acts and a set of different types of relations between offered propositions.

Power (1979) introduced the idea of a shared goal tree, where the responsibility for various nodes is either shared or distributed between two agents engaging in dialogue relating to the joint solution of a problem. Power also emphasised the goal-directed nature of speech acts. The work by Power (and others on goal-directed dialogue) complements Baker's work in that taken together, this body of research provides the theoretical basis for linking speech acts to the goals of interactants over a period of time.

Building systems that promote dialogue in learning interactions has long been a concern of ITSs research. However, only a small body of research has examined how to systematically use empirical data, taken from dialogue analysis, to inform teaching agent design. Blandford (1991) used empirical work to design an agent to support and improve people's decision making in the domain of design evaluation in engineering. Furthermore, Winograd and Flores (1986) demonstrate an approach to representing networks of speech acts which they call 'conversations for action'. These state transition networks can form the basis for computer tools and are thus a useful approach.

In the AI literature the term 'agent' is widely interpreted and many important issues remain unresolved. Kiss (1988) has proposed a theoretical model of an agent. In Kiss' model an agent has three classes of attitude: cognitive, conative, and affective. Kiss suggests that an agent architecture needs to support these different classes of attitudes in order to support the requirement for action (conative class), re-action to the environment (cognitive class) and autonomy (affective class). Blandford (1991) has already proposed, implemented and evaluated a teaching agent based Kiss' framework of attitudes. The dialogue component of Blandford's agent is capable, amongst other things, of engaging in purposeful dialogues and collaborative problem solving. However, it would appear that the agent theoretic concepts of Kiss and Blandford have not been further explored by the pedagogical agent community.

2.6 Implications for empirically based teaching agent design

From the above discussion it can be seen that a rich source of data for analysis can be obtained by studying human teachers and learners. Face-to-face dialogues provide an unconstrained source of phenomena in pedagogical interactions. Studies of such learning interactions can potentially expand our knowledge of the detail of how a human teacher interacts to support learning. Since fine-grained data is required from interaction analysis to inform teaching agent design, the findings can help uncover the causes of, and processes involved in learning. Commonly used goals, and actions to achieve those goals, can then be modelled in a teaching agent on the basis of empirical data. Alternatively, such an understanding can be used to structure the design of a computer-based learning environment so that it supports the desired learning goal.

However, a very basic *problem* raises its head in the form of the following question: how can studies of dialogue and interaction be exploited in a practical way by designers of teaching agents? It is difficult to extrapolate from human-human interaction to what can be supported in, or simulated for human-computer interaction in an agent-based learning environment. Very often, type-written dialogues are not as rich as face-to-face dialogues. A good example of studies that use the former approach is an explanation from an expert to a learner via screen and keyboard in the Wizard of Oz Technique; see for example Winkels (1992, pp. 28). The study dialogue is more likely to be of a broader "bandwidth" (Fox, 1993, Chapter 8)[18], i.e. contain more communicative information, if it is face-to-face (as in the case of the empirical study described in Chapter 5 of this thesis). In both study approaches (type-written and face-to-face) the human expert is asked to perform the functions of a future interactive system. However, humans are able to perform teaching functions that a future system is very unlikely to be able to mimic. Thus, going from a determinate corpus (which represents a set of behaviours of what is done by one teacher) to a future system (what should be done by the computer agent) is problematic: what kind of findings should be used in the future system?

The work described in this thesis *addresses this problem* by presenting a theoretically motivated framework for interaction analysis and modelling (the KMf described in Chapter 3). The framework is then linked to the concrete (framework category fit to data generated by the empirical study described in Chapter 5) in order

[18]Fox's work operates at a lower level of analysis than the level of analysis proposed by Kiss. Fox (1993, p. 15) uses an approach to dialogue analysis based on Conversation Analysis: "The major components of the methods and practices that are used both to analyze everyday conversation and to construct it in the first place are: *turns*, produced in general by one person; and what are called *adjacency pairs*, produced in general by different parties. With these two sets of notions, we can describe much of what happens in conversation."

to generate results (i.e. models of interactions) that can be used to motivate the design and implementation of a teaching agent (which is described in Chapter 6). We will *argue* that it is not simply a question of direct transference of the corpus to a system, rather, it is one of incorporating some functionalities from the corpus, and then, extending them to what an artificial teaching agent can do in addition.

Chapter 3 - Theoretical Framework (Knowledge Mentoring framework)

As we described earlier, although dialogue is important in promoting learning, especially in problem-seeking domains, we do not have available to us the precise details of the mechanisms of interactive learning in these domains. This problem is compounded by the finding that when students interact with computer-based music systems, reflection does not automatically take place; some students have to be encouraged to reflect in some way. One approach to building systems to address these problems is to base system design on the study of human teacher-learner dialogue and interactions. In this chapter we draw on theory from the literature to propose what we will describe as a 'theoretical framework', i.e. the Knowledge Mentoring framework (KMf)[19]. This theoretical framework was developed as a way of addressing the above problems. The KMf is the first component of our systematic design approach. Our approach to the design of teaching agents proposes a set of coherent relations between a theoretical framework, an analysis technique, a computational model and a computational implementation.

In subsequent chapters we will draw upon our theoretical framework in four important respects: (i) to devise seven protocol analysis techniques, (ii) to guide the formulation of various empirical results, (iii) to inform the design of the computational model of a teaching agent (in combination with some of the empirical results), and (iv) to guide a computational implementation (MetaMuse) of aspects of the wider computational model.

In this chapter we describe the three sub-components of the KMf: a goal-based approach to mentoring (hypothesised goal categories based on theory), a three-level framework (of goals, subgoals and communicative acts) and a theoretical model of a

[19]The initial proposal for the Knowledge Mentoring framework as an approach to linking interaction analysis to teaching agent design was first put forward in a paper presented at EuroAIED 96, Lisbon, Portugal (Cook, 1996b).

teaching agent for mentoring interactions (that includes values, wants, commitment, intention and an action cycle).

3.1 Goal-based approach to mentoring.

In this work, the meaning of the term 'mentoring' (reviewed in Section 2.2.1.6) has been expanded to include aspects of creative thinking. Mentoring goals (specific pedagogical goals) are achieved by intermediate sub-goals that will intend different types of interaction depending on the goal type. The six mentoring pedagogical goals (shown in italics) intend to (i) promote in the learner vision and *creative thinking,* (ii and iii) use *metacognitive interventions* to promote learner *metacognitive thinking* (monitoring and reflection), (iv) challenge the learner to think *critically,* (v) encourage in the learner *motivation* to learn, and (vi) support the *task.* Each of these mentoring pedagogical goals are now discussed in detail below.

The *creative thinking* goal draws on the metacognitive concept of going-beyond and going-above, which were described in Section 2.2.1.3. Going-beyond refers to the what-if aspect of knowledge-of cognition. Creative thinking has aspects of going-beyond when a learner imagines a novel opportunity. A learner needs to go-beyond, as it were, before they can then go-above and make a prediction (the latter involves the regulation-of knowledge). An example of going-beyond and satisfying the mentoring sub-goal 'creative imagine opportunity' would be a learner utterance like "I think I'd like to make my phrase a bit more chromatic actually". The creative thinking goal also encourages problem-seeking in that learners are being encouraged to place an emphasis on seeking out the problem that they want to solve. Regulation-of cognition is like going-above and looking down on one's own thinking, an internal, conscious reflective awareness about strategies and thinking about-thinking and action. An example of going-above would be what mentoring calls 'creative make prediction'; an example of which was given above in the illustrative example presented in Section 1.4.

The creative thinking goal also has some similarities with the metacognitive process of 'reflective access' (Brown, 1987; Self, 1993). Self (1993) describes 'reflective access' as follows:

> "Let us say that an agent has reflective access to a piece of knowledge if it can access, describe and discuss that knowledge in a way that maps onto its actual use by that agent." (Self, 1993, p. 2)

If learners are able to describe and then correctly play a series of transpositions to a motif, they would be said to have reflective access to that knowledge. That is to say, the ability to make correct predictions is equivalent to an ability to discuss knowledge in a way that maps onto its actual use. However, although the learner may be said to have reflective access to the knowledge, this access may not yet be creative reflection, which has a further requirement for imagined opportunities and predictions to occur in novel situations. Novelty as part of creativity is a contentious issue (Boden, 1990, p. 3). However, creative reflection is more than 'mere novelty'. As part of the learning process creative reflection is viewed here as a prerequisite ability that allows for the potential of 'genuine creativity' in musical composition.

Metacognitive intervention and *metacognitive thinking,* as mentoring pedagogical goals, extend Self's (1993) DORMORBILE architecture for reflection and monitoring; there is some (unavoidable) overlap between the previously mentioned two pedagogical goals and the creative thinking goal described above. The only sub-goal for *metacognitive intervention* is 'target M or Ref', which is described in detail in the next section (3.2). There are two types of *metacognitive thinking:* monitoring and reflection. Monitoring has two sub-goals: 'monitoring evaluate' and 'monitoring diagnose' (both monitoring sub-goals require the learner to go-above and regulating their own knowledge). Monitoring refers to one's on-line awareness of comprehension and task performance. The ability to engage in self-explanation when learning is a good example. Monitoring goals (M) are usually indicated by communicative acts that are either evaluative (e.g. 'that doesn't sound right') or a diagnostic utterance (e.g. 'I got my counting wrong'). Reflection (Ref) by a learner may not always be translated into a linguistic act and hence poses a serious problem for interaction analysis. A silence or some vocalisation like 'umm' may be indicative of reflection depending on the context. Reflective thinking may involve 'going-beyond' type thinking and hence tends to overlap with the creative thinking goal.

Critical thinking is defined here as thinking that facilitates judgement because it relies on criteria, is self-correcting, and is sensitive to context (Lipman, 1991, p. 116). (See Table A2.1, in Appendix 2 for an elaboration of this definition.) The critical thinking goal, taken with the creative and metacognitive thinking goals described above, are compatible with the three components of critical thinking identified above by Sternberg (1985).

Ashman and Conway (1997, p. 53) have proposed that cognitive, metacognitive, and motivational factors predict 'good' and 'poor' performance in learning and problem solving. Hence, *motivation* is included as a mentoring pedagogical goal. Motivation is the sense of a willingness to pursue activities and in mentoring has three sub-goals: 'motivation extrinsic' (e.g. qualifications dependent on passing exams), and 'motivation intrinsic' (e.g. a prior interest in the subject) (Draper, 1994, p. 11), plus 'motivation encouragement', which is meant to keep interactions flowing smoothly.

A *task goal* is a description of what the teaching and learning interactions will have the underlying aim of achieving, it provides a statement against which learning outcomes can be measured. Explaining the nature of a task goal would be achieved (by the teacher) directly by communicative acts or action. Actually attaining task goals would be achieved by other mentoring pedagogical goals. That is to say, the task goal may have other pedagogical goals nested within it, and that the converse may also be true. In interaction, there will be an underlying task structure from which, at certain points, other mentoring goals branch off or become achievable. For example, at one point a critical thinking goal may be dominant (e.g. a sub-goal 'probing'), however, the goal of that segment of interaction may in fact be to get the student to think about or adopt the desired task goal, e.g. use interval leaps to transpose the motive. Once the student is pursuing a task goal, other mentoring goals may then become applicable.

3.2 Three-level framework

In the KMf, interactions in musical composition learning are viewed as having two related aspects: internal 'dialogue' (i.e. agent monitoring and reflective pauses) plus external interaction with other agents. The KMf thus has a Vygotskyian (1978) conception of learning, where the teacher mediates knowledge about the society and culture so that it can be internalised by the learner. This is similar to what Lipman (1991) calls 'thinking that is self-correcting', i.e. where a participant in a "community of inquiry" is able to internalise the methodology of the community (where members begin looking for and correcting each other's methods and procedures) as a whole, each is able to become self-correcting in his or her own thinking.

We have previously proposed (Cook, 1996b) that some teaching interventions have 'implicit intentions' that will vary in their purpose, depending on the metacognitive level in the learner being targeted: (i) some of which are designed to promote Reflection (Ref) in a learner, e.g. What else could you do with that scale? Can you generalise this to another area of your compositional work?, and (ii) some of which are designed to set up Monitoring goals (M) in a learner, i.e. to help them assess the progress of their own learning, e.g. Is that what you intended? Thus, for example, a teacher may reflect (internal dialogue) on which intervention (external interaction) will best promote monitoring in a learner (implicit intention of adding a goal in the learner's head). In the illustrative example given earlier (Section 1.4), the teacher made various question interventions that seemed designed to verify if the learner was composing in an intentional manner and that were *targeted* at the learner's monitoring level (an attempt was made to get the learner to accept the goal of explaining why the musical outcome did not match the expectations as described in an earlier prediction by the learner).

Pursuing the overall goal of creative reflection will entail the teacher encouraging the student to verbalise their compositional ideas, i.e. to give a self-explanation (Chi, Bassok et al., 1989; Chi, de Leeuw et al., 1994). For composition this might be in the form of a prediction about how a phrase just created will sound when played. An example (from session 3 of the study described in Chapter 5) of a learner making a prediction about their phrase would be:

> **Learner:** Emm, the first one [phrase] is just coming down in semi-tones, so it's going to be the motif coming down a semi-tone each time. The next one [phrase] I've done it so it leaps down back to the original, the middle C. Then up.

Becoming competent at creative reflection involves increasing success by the learner at the elaboration of detailed mental structures of musical phrases, which implies motivation to practice the building of these structures. Mozart, apparently, could be simultaneously aware both of a composition's articulated inner structure and of its overall form (Boden, 1990, p. 251). Although we can not expect every student to have the abilities of Mozart, it is reasonable to assume that their abilities at creative reflection can be improved with training. Mozart was put through a strict musical training programme by his father (and mentor) from a very early age, which may in part account for his genius: "In short, a person needs time, and enormous effort, to amass mental structures and to explore their potential." (Boden, 1990, p. 254)

In interactive dialogues, such as those proposed in the KMf, the goals that a teaching agent may generate to promote creative reflection may get disrupted or may require adaptation to meet the needs of the learner. Cooperative interaction between a teaching and learning agent may, therefore, involve the negotiation of plans that were invoked to satisfy a goal and the sharing of responsibility when executing plans. Interactions in learning can, therefore, be seen as social actions in the sense that the action is intended to have an effect on the other agent (i.e. there may be an implicit intention behind an intervention, as the motivating illustrative example in Section 1.4 illustrated).

The KMf draws on Power's (1979) suggestion (reviewed in Section 2.3.1) of shared and distributed hierarchies of goals and speech acts. *There are three levels in the KMf.* First, we have the *Pedagogical Goal level* (an agent's internal goals, what Power calls "the higher goal G"), which has six (mentoring) goals that relate to: creative thinking, metacognitive interventions, metacognitive thinking, critical thinking, motivation and the task. Second is the *Intermediate Sub-goal level* (an agent turn), which can, for example, include a 'probing' sub-goal that is related to the critical thinking pedagogical goal, or the 'monitoring evaluate' sub-goal that relates to the metacognitive thinking pedagogical goal. The third level, the *utterance level,* includes *'Communicative Acts'* or CAs (Bunt, 1989; Baker, 1994). The main CAs in the KMf are: assert, question, offer, request, accept and reject; as well as actions like playing music and pointing at the computer screen.

The general approach taken to analysis in the KMf is to take an interaction, divide it into goals and sub-goals (each goal may consist of a number of agent sub-goals, i.e. turns), and to then formalise each sub-goal (a turn) into an utterance. An utterance is composed of a *move function* and a CA (Baker, 1994). A CA is the smallest monological unit, an illocutionary act realised by verbal or physical action. A move function is a CA once put into the context of an interaction itself. The move function specifies the function of a CA in a particular context. An utterance is usually a string or unit of linguistic signs that can be separated from another unit in some way, e.g. by syntax, semantics, pauses, etc. In the KMf, an utterance is a unit that corresponds to a KMf sub-goal (turn) higher up the hierarchy (at the intermediate level). A turn may be realised by a set of utterances. Each utterance is composed of a CA, which may in itself realise different move functions. The goal trees for the teacher (which are motivated by empirical work given in Section 1 of Appendix 4) are given in Figure 3.1 (parts 1 and 2).

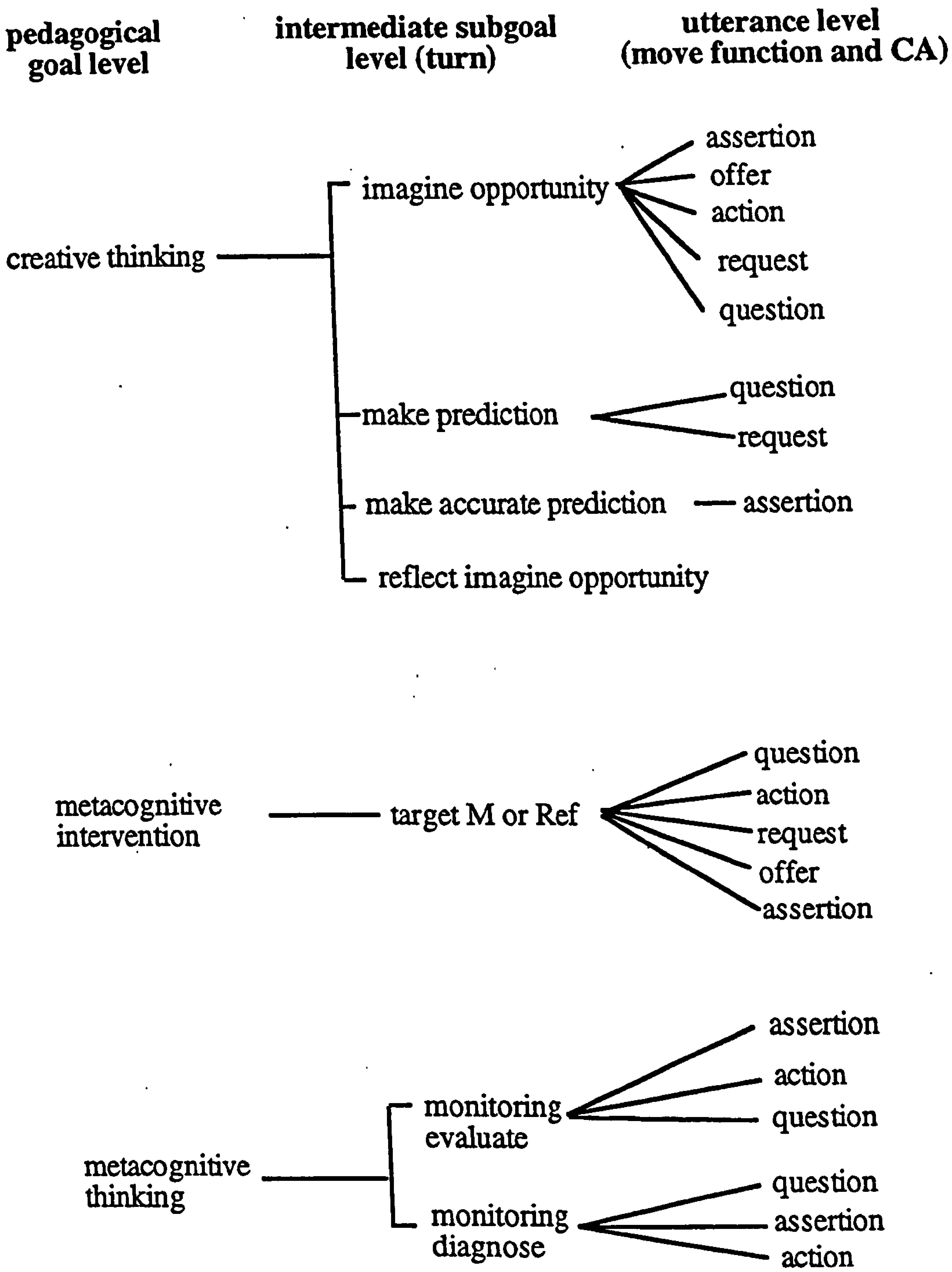

Figure 3.1 (part 1). Goal trees for the teacher.

What Figure 3.1 shows is a set of partial hierarchies in that no link is specified for joining the different goal trees shown (this link between goals is addressed in the empirical work below).

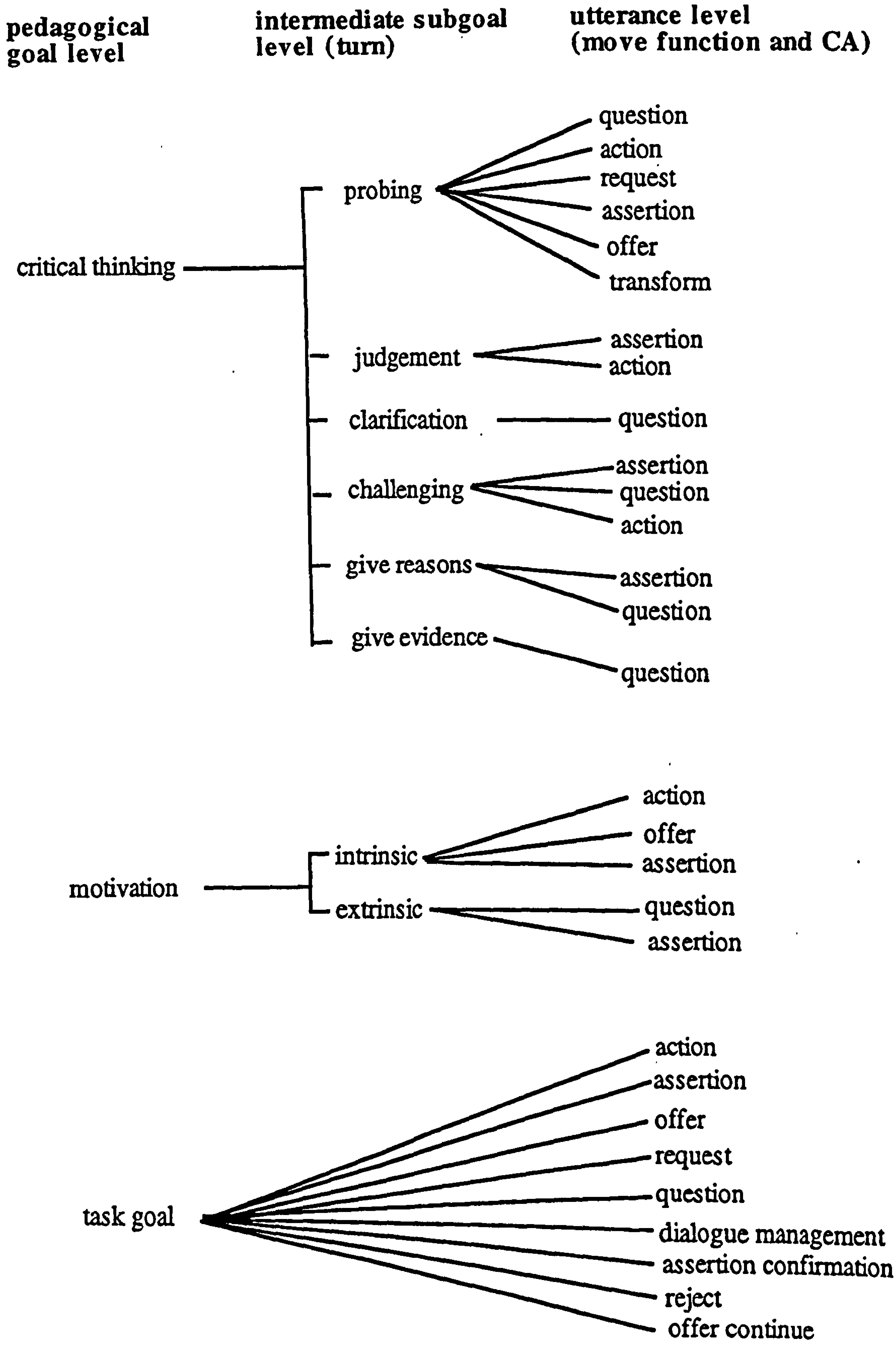

Figure 3.1 (part 2). Goal trees for the teacher.

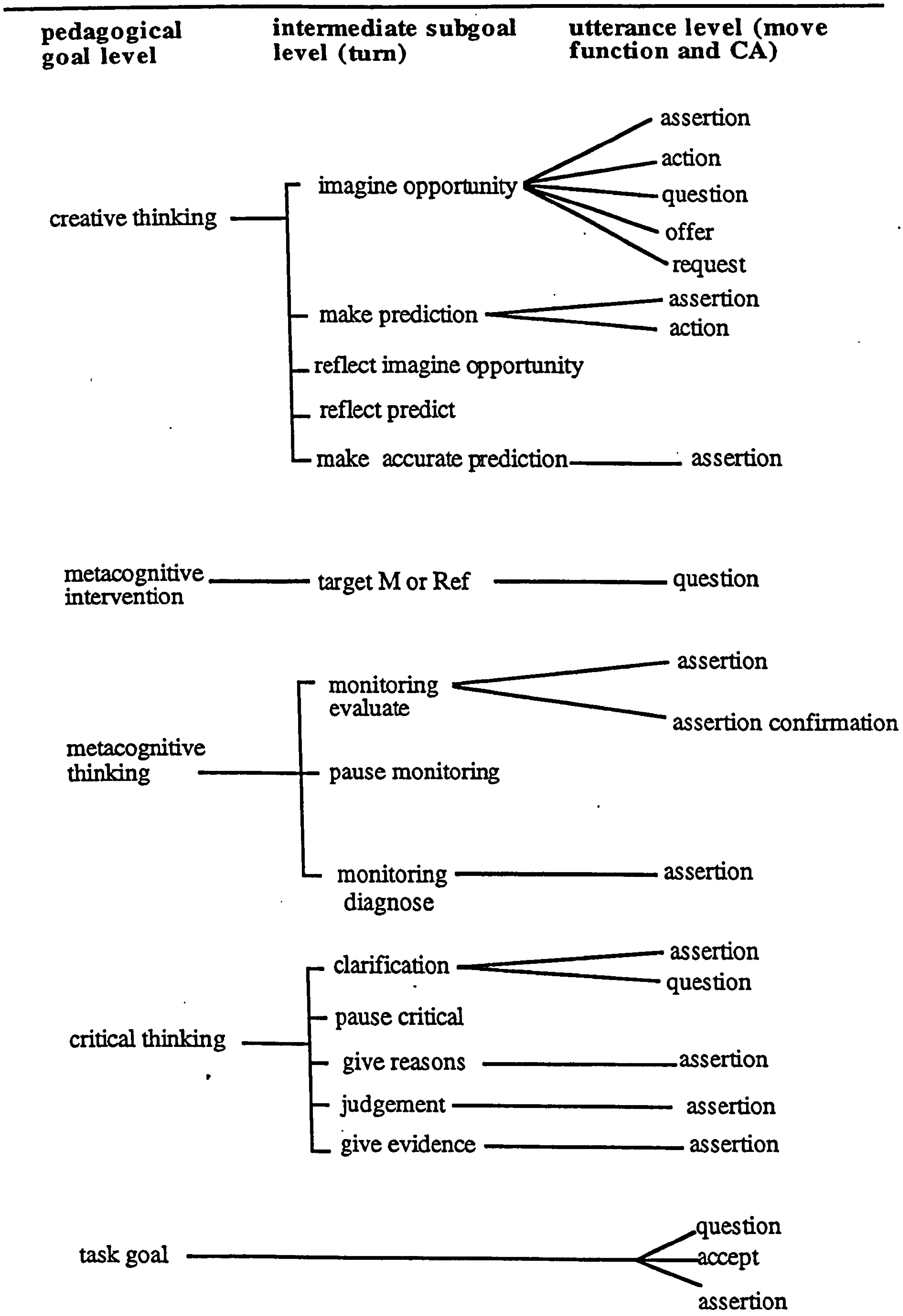

Figure 3.2 . Goal trees for the learner.

Note that one or more different utterances may be used in an agent turn to introduce a goal, and that this feature is captured in the goal trees at the utterance level. (See the Appendix 2 for a summary of the goal, sub-goal and utterance categories used in the goal trees.)

The basic structure of the learner goal trees and the utterances used to achieve them (which are motivated by the empirical work given in Section 1 of Appendix 4) are shown in Figure 3.2. Again, this is actually a set of partial hierarchies in that no link is specified for joining the different goal trees shown in Figure 3.2.

Figures 3.1 and 3.2 show that some goals may be used exclusively by one agent. For example, 'probing' and 'challenging', plus 'motivation intrinsic' and 'extrinsic', are used only by the teacher. At the utterance level there are some interesting differences. For example, when first discussing the task goal (Figure 3.2) the learner would only use three acts (question, accept and assertion). However, the teacher uses nine utterance categories when introducing a task goal (Figure 3.1, part 2).

In the illustrative example given earlier in Section 1.4, the teacher asks the question (his second utterance) "What did you expect?". This is a question CA at the utterance level that links to the 'target M or Ref' intermediate sub-goal level (shown in Figure 3.1 part 1, where M = Monitoring and Ref = Reflection). It may also have the move function of "the teacher wants the learner to say why the phrase they have just listened to did not meet his (the learner's) expectations". This move function links it to the teaching agent's turn (intermediate sub-goal level) of targeting the monitoring level of the learner ('target M or Ref'), which is itself linked to a higher level pedagogical goal which intends to make a 'metacognitive intervention'. In the illustrative example (Section 1.4), the learner replies "Err, I got mi, I got mi countin' wrong". This may be an assertion CA, but in the context of the teacher's previous CA, it can take on an explanation move function. This learner explanation 'move function' is also linked to the learner's turn (intermediate sub-goal level) of 'monitoring diagnose', (which is shown in Figure 3.2) which is itself linked to a 'metacognitive thinking' goal (pedagogical goal level) even further up the learner's goal hierarchy.

'Offer' as a communicative act in the KMf keeps the essence of Baker's (1994) negotiation in that they can be accepted or rejected (i.e. they are conditional, "I will accept if you will accept"). However, in the KMf there is less negotiation about what to do and more emphasis is placed on how to proceed with a task if accepted. In this respect 'offer' in the KMf has some similarities with 'offer' in Fox's (1993) approach.

There are only six primary acts[20] in the KMf (because we are more concerned, in this work, with the high-level goal structure of interactions). The six acts are assertion, question, request, offer, accept and reject. The use of primary acts means that certain aspects of an utterance may not be captured (the move function). For example, utterances that are acts of explaining or answering would be coded as assertions in the KMf. They are assertion CAs that realise the move functions of explanation or answering. However, the use of a limited number of acts in a framework is not unusual. In Cohen and Perrault's (1979) work, agents are represented in terms of beliefs and wants. Kiss (1986, p. 15) points out that as a consequence, the scope of their work is confined to speech acts which can be characterised using beliefs and wants, i.e. requests, informs, and questions. They explicitly exclude promises and warnings.

The approach taken to representing communicative acts in the KMf thus differs from the communicative actions proposed by some other researchers. For example, Bunt (1989, p. 63-64) identifies 22 acts, or communicative functions as he calls them, which have associated with them various appropriateness conditions that specify when an act is relevant for selection. Bunt would probably call primary acts 'general functions' (Bunt, 1989, p. 64). The reason for taking this more constrained approach to the number of acts used in this framework is, as was pointed out above, that this work is mainly concern with identifying aspects of high-level mentoring interactions. High-level interaction is concerned with the overall goal structure of interactions rather than the detailed structure of a communicative act. Furthermore, in the KMf we took the decision to use a limited number of acts in an attempt to gain

[20]Some acts are specific forms of primary acts e.g. assertion confirmation is a specific form of the primary act assertion.

future computational advantage (i.e. to reduce complexity and hence increase the potential for the goal trees to be implemented in a teaching agent).

To summarise, several different CAs can be used to achieve a given goal; therefore analysing at the goal level would, it was hoped, enable us to analyse the structure of interactions at a useful level of detail, but for an extended length of time (over two hours of interaction data was eventually analysed in the study described in Chapter 5). However, once a goal is at a sufficiently low enough level in KMf hierarchy, it forms a commitment at the utterance level to communicate, and so a limited number of primary communicative acts are included in the analysis framework.

3.2.1 Example of partial goal trees in the KMf.

In order to give a flavour of the partial goal trees in the KMf, a limited number goals, communicative acts and actions are now discussed in more detail. At the utterance level 'question' for the 'critical probing' sub-goal has a special meaning for the mentor. Consider the following example of 'critical probing' by the mentor in session 1 in the study described in Chapter 5 (which was coded as using 2 questions and 3 actions to satisfy the occurrence of the intermediate level turn goal of 'probing'):

> =Yeah. It might, these, these [USES 'I' BAR TO POINT TO 28 AND 24] surprises that you you mentioned // very large leaps. Umm. Do they, segment the music? Or do you, do you see that jump there [POINTS WITH FINGER TO 28] triggering this little phrase here? [PULLS CURSOR OVER 2 2 1]

By drawing on Bunt's (1989, p. 62-64) approach, the above interaction can be represented by using various conditions that specify when the communicative act question is an appropriate one for satisfying the 'critical probing' intermediate goal:

> Mentor believes p, where p is the proposition that elements of $x_1 \ldots x_n$ segment the musical

phrase

AND

Mentor suspects learner phrase not intentional with respect to p

THEN

Mentor commits to goal of discovering whether y or not y, where y = exists intention of learner behind action AND discovering what this intention is with respect to p

Once committed, CAs that satisfy the 'probing' sub-goal can vary. For example, 'probing' can be achieved by CA question, or by a CA assertion which has the move function of "remind student of their intention when they did something similar". Once y has been established, the mentor could correct or comment on it. 'Critical probing' is therefore related to finding out about a learner's intention (in the broader sense of regulation-of knowledge). This sets it apart form the 'information-probing' used in Levin and Moore's (1977) dialogue games. They define information-probing as

"Person 1 wants to know whether Person 2 knows some particular information, and interacts with him to find out." (Levin and Moore, 1977, p. 400)

'Critical probing', on the other hand, wants to check a learner's intentionality with respect to some propositional content (a proposition about some topic), i.e. the mentor wants to check the learner's regulation-of knowledge in terms of planning and prediction. The question here has the illocutionary point of a 'directive' to the hearer to make a 'declaration' about his intentionality with respect to some propositional content.

The use of the question communicative act in 'probing' is very different to its use in 'metacognitive intervention' intermediate goal of 'target M or Ref' (i.e. target Monitoring or Reflection levels in the learner). Consider the following example of 'target M or Ref' by the mentor in session 2 of the empirical work described in

Chapter 5, which has been used following the playback of a musical phrase:

Is that close to what you, intended?

This is an attempt by the mentor to get the learner to say if there is a match between how they predicted the musical phrase would sound and what actually happened. Essentially the mentor is targeting the monitoring level of the learner, in the hope that they will accept the goal and explain verbally what they think about their own attempts at creative reflection. This can be represented as:

Mentor suspects learner not accurately predicted musical outcome

OR

Mentor wants to elicit learner monitoring or reflection

THEN

Mentor commits to directive wh-question with intention of getting learner monitoring-assertion

The act used for 'target M or Ref' has the communicative function of what Bunt (1989) would call a wh-question or what Searle (1976) would call a directive (the mentor wants-hearer to accept the goal of monitoring or reflecting on what they have just heard and is 'directing' the hearer to make a monitoring-assertive act in response). The question is open-ended because it leaves space for the learner to attempt to integrate new knowledge (what actually happened when the phrase was played back) with existing knowledge (the learner's prediction) by giving a self-explanation. Unlike the 'critical probing' question, the 'target M or Ref' question makes no reference to any propositional content.

In summary, in the KMf the teaching agent values creative reflection (an agent attitude). In order to satisfy its values, a teaching agent derives pedagogical and intermediate goal hierarchies. The agent has the overall intention of taking action to uphold its values by pursuing a combination of pedagogical goals. A pedagogical goal (e.g. the mentoring pedagogical goal 'critical thinking') would plan an intervention by selecting an *appropriate* intermediate turn goal (e.g. 'critical probing'). Intermediate and task goals are achieved by communicative acts and action. The 'critical probing' sub-goal (intermediate level) would usually form an intention to commit to the communicative act 'question' form, since, according to the appropriateness conditions related to a pedagogical goal back up the hierarchy, the mentor suspects that the learner has developed the phrase in a non-intentional manner with respect to p, where p is a proposition. One of the purposes of the interaction analysis described in Chapter 5 of this thesis was to discover what a mentor takes to be an *appropriate* goal or act, and to uncover why and when it was deemed appropriate.

3.3 Theoretical model of teaching agent

In our theoretical model, a teaching agent can be viewed as *valuing creative reflection*. Values are affective agent attitudes. Affective attitudes express values with respect to other attitudes or agent states in terms of liking or disliking (Kiss, Clark et al., 1988). In the theoretical model, a teaching agent valuing creative reflection means that the agent 'likes' to encourage the learner to 'verbalise their compositional plans and intentions and to monitor and reflect on the outcomes of action'. An agent is understood to be an integrated natural or AI system where, in order to satisfy their values, agents derive goals from them and then form intentions to take action to reach these goals. Thus, a value is attached to possible situations of promoting learner creative reflection. The agent may then decide to form a further attitude of wanting the possible situation of creative reflection, this want will lead the agent into adopting pedagogical goals, because it already has the attitude of valuing these pedagogical goals because they can promote creative reflection.

Since the description of an agent provided by Kiss (see Section 2.4.1 for a review of this work) is very similar to the goal hierarchy and acts used for our multi-level framework (see Section 3.2), it has been adopted here as part of the motivating theory of our teaching agent.

The teaching agent attitudes included in our theoretical agent model are similar to Blandford's model (1991), with the exception of motivation (see Section 2.4 for review of agent attitudes). Attitudes included in the KMf are acceptance (a conative attitude) and mutual beliefs (cognitive attitudes), goals, wants, intentions, commitments (conative attitudes), and values and motivation (affective attitudes). Note that goals refer to aspects of the state of the world, whereas wants, intentions and commitments refer to actions

Standard beliefs (held by the agent) are not represented explicitly in the model (i.e. a fine-grained user model of user misconceptions is not maintained). Agents may 'accept' to work together, perhaps accepting some proposition for now whilst not really believing in that proposition or indeed being committed to the proposition. This is what Blandford calls working beliefs (1991, p. 122) and what Baker (1994, p. 205) refers to as acceptance. Simple beliefs about what is expected and what has been accepted are encoded. Other beliefs encoded include beliefs about the task, and about pedagogical and intermediate goals. As we describe in Chapter 6, a belief structure is maintained of what the learner states he or she believes with respect to certain goals.

Wants refer to a list of actions an agent might be willing to be committed to, commitment refers to the chosen way of achieving an action. In the teaching agent model, an agent forms an intention to commit a particular communicative act. Present-direction intention is the same as becoming committed to some action. Future-directed intention (Bratman, 1990) is tied up in the plan. No hedonic values (e.g. pleasure) are represented in our theoretical model of the teaching agent. The agent value represented is pedagogical (concerned to be mentoring well, as defined by the analysis of human tutoring). Values cannot be achieved or abandoned like goals can. Values are persistent.

As we saw in Section 2.4, Blandford has already proposed a dialogue agent based on Kiss, Clark et. al's (1988, p. 34) notion of an action cycle (Blandford, 1991, p. 126). The teaching agent model, or action cycle, in this thesis draws on the above work by Kiss et al. and Blandford to propose a teaching action cycle (shown in Figure 3.3), which is also based on the empirical results presented in this thesis (Chapter 5). The action cycle determines what action the teaching agent is to take at each time increment of the current situation. Following Kiss, Domingue, et al. (1991) in our theoretical model, a teaching agent is characterised in terms of:

> "what it perceives,
>
> what it knows,
>
> what kind of reasoning it can do,
>
> what values and goals it has,
>
> what actions it can take
>
> and some related agent-theoretic concepts."
>
> (Kiss, Domingue et al., 1991, p. 3)

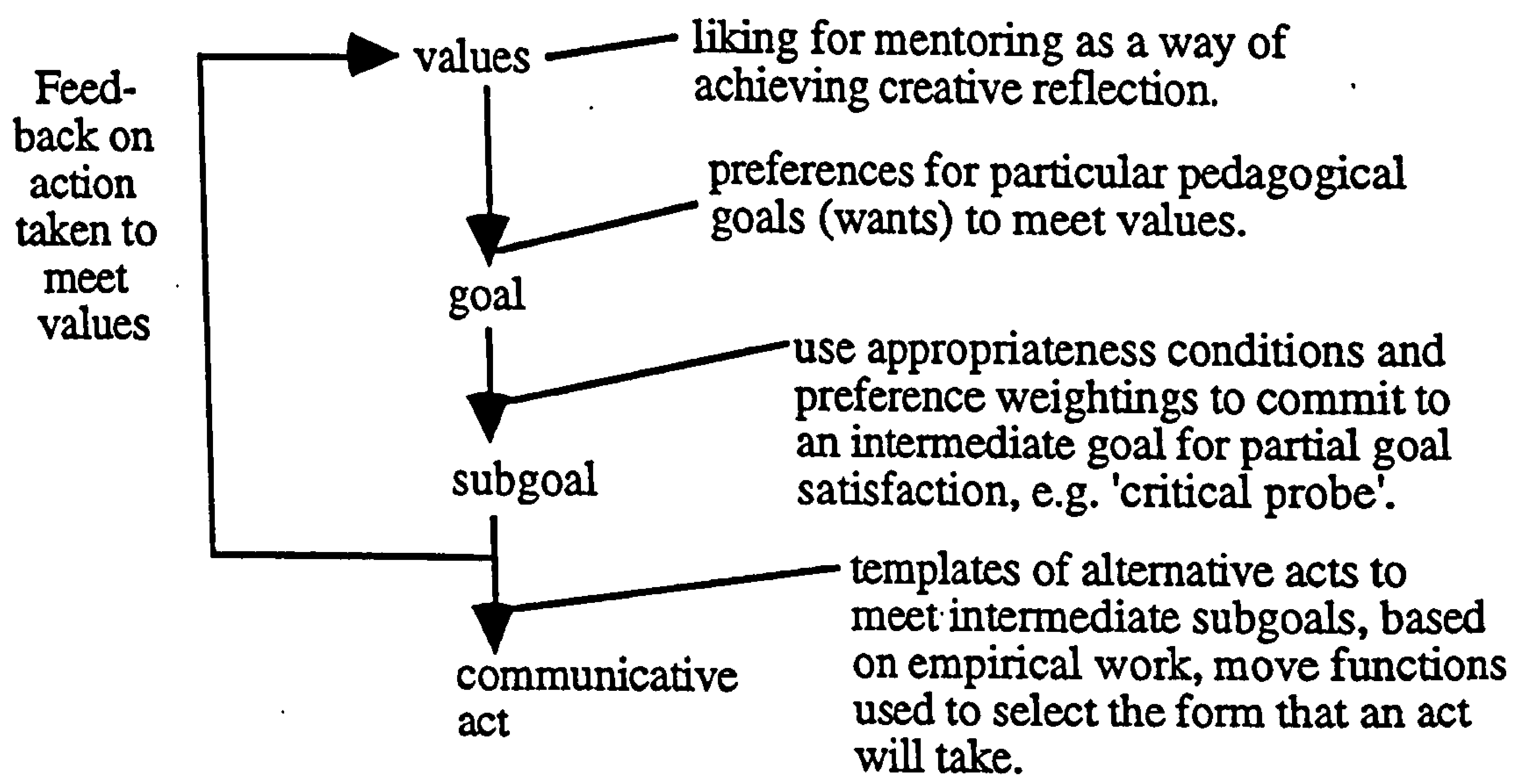

Figure 3.3. Teaching agent action cycle.

The above characteristics of the teaching agent are discussed in detail in Chapter 6 in the context of the design of the teaching agent (i.e. our computational model). The teaching agent has some plans about how to proceed (empirically derived state transition networks of sub-goals that define preferred interaction routes). Usually, these networks specify the sub-goals that can be selected at a particular point in time. The agents take turns. Each node in a network thus constrains the currently active agent to a particular selection of sub-goals. If it is the teaching agent's turn it may make a suggestion about which sub-goal it would prefer the learner to select (when it becomes the learner's turn) from the exit transitions that will be made available to the learner for the current node in the network (e.g. if there are three possible learner exits from a node, the teaching agent will make all three exits available but may suggest that the learner selects one exit in particular). If the learner does not accept a suggestion from the teaching agent, then they are free (within limits) to select one of the other options that are available. Thus, limited adaptations of the plans can take place and a simple user model is updated.

When it is the teaching agent's turn, it forms an overall intention to satisfy its values. In our theoretical model, this takes the form of the teaching agent generating a list of sub-goals that are available to it at the current node in the network (this list is called 'wants', the agent wants to satisfy all of its possible sub-goals for a particular network node). Once committed to a particular sub-goal[21], the agent forms an intention to take action (i.e. to make a communicative act).

Our motivating theory of a teaching agent builds on some aspects of Blandford's (1991) work and extends it. Our work, for example, builds on Blandford's in that in our own theoretical framework (and computational model) we specify the theoretical requirement to use empirical data to make decisions about how to become committed. We extend Blandford's work, for example, by insisting on the use of empirically derived state transition networks as the basis for planning in our computational implementation. These networks are used as initial plans in an attempt

[21]The process of becoming committed is part of a decision making process which is described in Chapter 6 in the context of our computational model.

to look at what is a reasonable interaction for the agent to engage in with the student (i.e. exit nodes limit the amount of reasoning the agent has to do).

3.4 Summary of theoretical framework (KMf)

Our theoretical framework (the KMf) has three aspects, which are summarised below: a goal-based approach to mentoring, a three-level framework and a model of a teaching agent for mentoring interactions.

There are six mentoring pedagogical goals. The *creative thinking* goal intends to promote in the learner the ability to imagine novel opportunities and to make accurate predictions about these opportunities. The *metacognitive intervention* goal aims to persuade the learner to accept *metacognitive thinking* goals (of monitoring and reflection). Other goals include challenging the learner to *think critically,* encourage in the learner *motivation* to learn, and the goal of supporting the *task.*

There are three levels in the KMf. First, we have the *Pedagogical Goal level* which has the six (mentoring) goals mentioned above. Second is the *Intermediate Sub-goal level* (a turn). The third level, the *utterance level,* includes *'Communicative Acts'* or CAs. The main CAs in the KMf are: assert, question, offer, request, accept and reject; as well as actions like playing music and pointing at the computer screen. A *move function* specifies the purpose of a CA once put into a specific context. In the KMf hierarchy some goals may be used exclusively by one agent. One goal can be used to represent several communicative acts; therefore analysing at the goal level would, it was hoped, enable us to analyse the structure of interactions at a useful level of detail, but for an extended length of time.

In the theoretical model of the teaching agent, an action cycle is used to determine what action the teaching agent is to take at each time increment of the current situation. When it is the teaching agent's turn, it generates a list of sub-goals *(wants)* that are available to it at the current node in a network (networks are empirically derived). The agent uses a decision process[22] to select the sub-goal that best meets its

[22] Which is part of the computational model described in Chapter 6.

current situation (i.e. the agent tries to become *committed* to one sub-goal). Once committed to a particular sub-goal, the agent forms an intention to take action and may use a move function to perform local planning before making a communicative act.

3.5 Implications of theoretical approach

The goal-based approach to mentoring described above was developed in order to explore the research questions described in earlier chapters. We argue that our synthesis of the existing work on creative, metacognitive and critical thinking into mentoring goals is a novel proposal for the problem-seeking area of musical composition. One weaknesses of our approach is the overlap, pointed out above, between some of the goals (e.g. between Self's DORMORBILE based metacognitive goals and the creative thinking goal). However, we would further argue that this 'overlap' weakness has not in fact been highlighted so far for problem-seeking domains. The reason for this may be that other definitions were not fine-grained enough. The KMf is actually refining other coarse definitions into separate, finer ones.

The KMf three-levels make an explicit link between the internal goals of interactants and the communicative acts used to satisfy goals. A teacher may reflect (internal goal) on which intervention (communicative act) will best promote monitoring in a learner (implicit intention of adding a goal in the learner's head). In this sense the KMf provides a synthesis of the work by Self, Power and Baker. A strength of the goal tree structure described in this chapter is that they are motivated by the theory reviewed in Chapter 2 and by the empirical work (given in Section 1 of Appendix 4). For the KMf to be readily generalisable to other areas, like the teaching of social sciences, then we would probably need to exclude the sub-goal, in our framework, relating to 'creative imagine opportunity' and replace it with sub-goals relating to, for example, inter-subjective understanding (see Goodyear and Stone, 1992).

The limited number of primary acts may be seen as a weakness of the KMf. However, such an approach does reduce complexity and hence increases the potential for the goal trees to be implemented in a teaching agent.

Our theoretical agent model extends earlier work both by proposing the use of empirically derived state transition networks as the basis for planning (these limit amount of reasoning the agent has to do) and by applying this work to the domain of musical composition. A limitation of our theoretical approach to teaching agent modelling is that it does not represent explicitly a fine-grained model of user misconceptions (e.g. belief revision). Overcoming this limitation would be the subject of another research project.

Chapter 4 - Research Approach and Methods

Initially, the research method used by this project involved a literature review (including on-line bibliographic searches) and a thesis proposal, the outcome of which was a Technical Report (Cook, 1993). A survey was then conducted of a small number of experts in the field of music education and music psychology (described in Appendix 1) who have conducted work related to the topics being researched in this thesis. Various research methods were then used to explore some specific research questions. We first discuss the general approach taken to research in this thesis, before describing these methods in Sections 4.2 and 4.3.

4.1 Research approach for thesis

As was pointed out in Chapter 1, the research approach adopted in this thesis has been one of conducting various studies within an iterative design context. Specifically, this has involved one approach to what has been termed User Centered Systems Design (Norman and Draper, 1986). User Centered Systems Design (UCSD) is an approach to asking:

> "what the goals and needs of the user are, what tools they need, what kind of tasks they wish to perform, and what methods they would prefer to use (p. 2) ... One view [of UCSD] ... is that design must be treated as fundamentally empirical. Designers must work hard to learn as much as possible about the users of the system and the work they will do with it. They must assume that their initial design ideas, even given this background information, will be wrong, and plan for repeated design. They must base these redesigns on empirical measurements of the success of the design, made on actual use of an implementation, a prototype, or a mockup." (Norman, Draper,

Lewis, 1986, p. 5)

Users in the context of our research are musical composition teachers and learners. This thesis used a research approach or cycle, shown in Figure 4.1, that combined framework construction (the Knowledge Mentoring framework, the final version of which is given in Chapter 3), empirical data gathering and analysis, learning environment building and teaching agent construction (computational model). This research approach is consistent with the author's field of research, which is Artificial Intelligence in Education. The approach was supplemented by various research questions which were used to focus the topic of research into a manageable area.

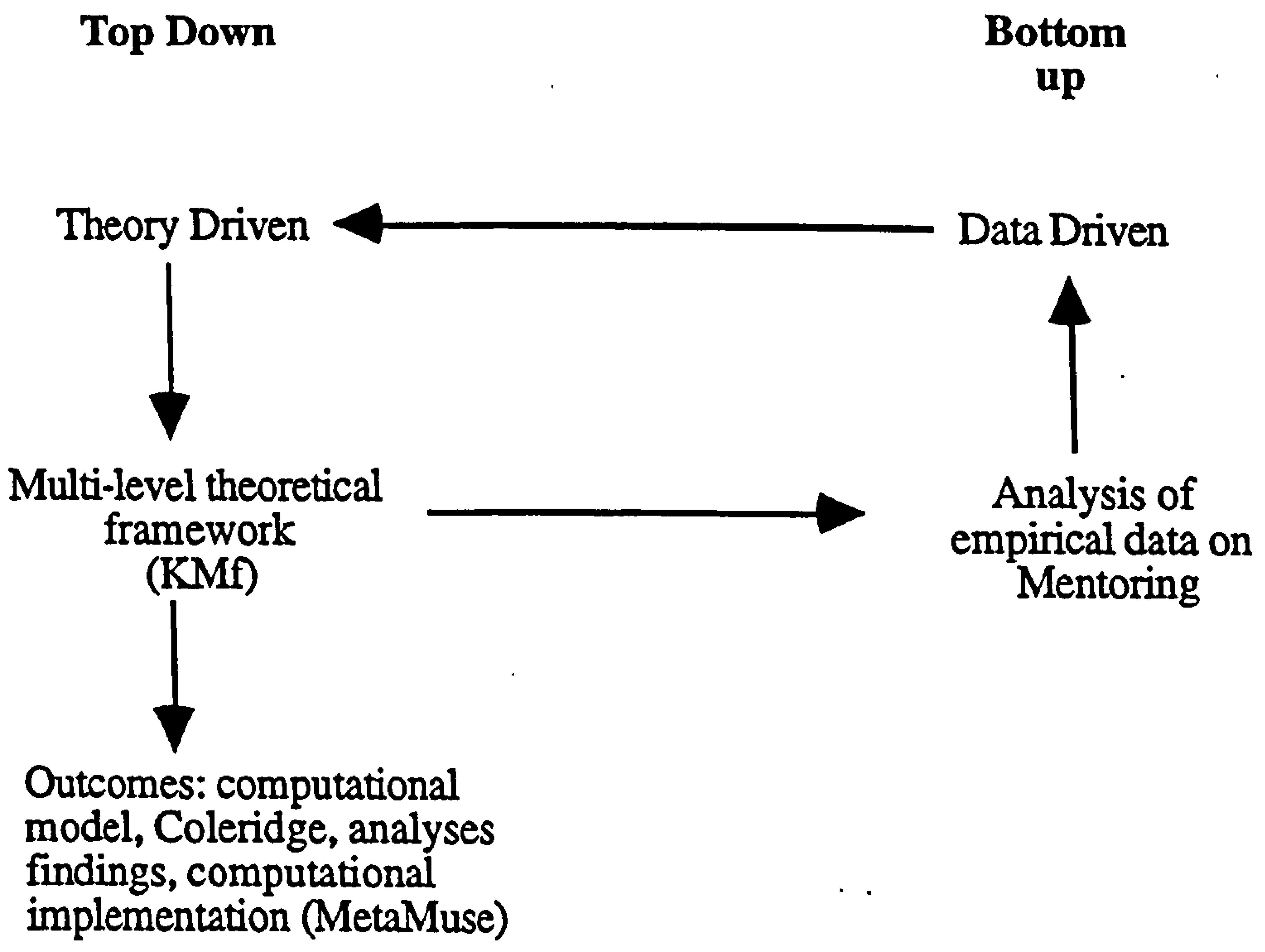

Figure 4.1. Research cycle, adapted from (Winkels, 1992, p. 27).

The research cycle shown in Figure 4.1 is top-down, theory driven, a multi-level theoretical framework developed from the literature (the Knowledge Mentoring framework or KMf) as well as being bottom-up, data-driven. The multi-level theoretical framework (KMf) guides the gathering of empirical data, the data gathered are used to validate and to refine the multi-level theoretical framework. Three distinct stages can be identified that are characteristics of this research cycle. First, propose (or refine) the multi-level theoretical framework on the basis of theory and any empirical data available or gathered (this includes categories of goals and communicative acts). Second, gather empirical data to validate and refine the multi-level theoretical framework (e.g. provide evidence of the goal and communicative act categories)[23]. Third, use the theoretical framework to inform the design of outcomes, e.g. computational model. In this sense the research approach used in this thesis can be said to be systematic (there is a strong relationship between theory, data analysis, computational model and computational implementation) as well as being iterative (a loop around the research cycle may, for example, provide a new version of the prototype teaching agent, i.e. the computational implementation).

The empirical study described in Chapter 5 had two purposes with respect to the overall research approach of the thesis. First, it took a 'design stance', in that by filtering the 'behaviour' of a teacher (i.e. constraining the interventions used by the teacher to achieving creative reflection by a process of mentoring) the study attempted to identify the range of teacher interventions that had the goal of stimulating creative reflection and identify interventions by the learner that indicated creative reflection had occurred. The purpose of the detailed analysis of interaction data was to then uncover a correlation between a teacher's goals, intentions and interventions for creative reflection and the student's attempts at creative reflection. The purpose was not 'just' "we are going to look at what a teacher does"; the main things to be said would, it was predicted, concern the effectiveness of mentoring (not its 'mere' occurrence). The second purpose of the study was also related to teaching agent modelling: a computational model for mentoring was evolved, based on several iterations of the research loop shown in Figure 4.1.

[23]In fact the theoretical framework presented in our thesis is based on at least two iterations around the research cycle (i.e. the earlier studies described in Section 1.5).

4.2 Research methods for empirical study

The research methods that were used for the empirical study described in Chapter 5 were a combination of complementary methods, involving systematic observation, post-experimental interviews, data transcription and qualitative data analysis to generate quantitative data. These methods were chosen because they provide an approach that is able to investigate in great detail the research question given in Chapter 1.

4.2.1 Methods

Systematic observation is "the process whereby an observer or a group of observers devise a systematic set of rules for recording and classifying classroom events" (Croll, 1986, p. 1). The approach is characterised by an observer who is non-participative. Such a method would, it was hoped, provide fine-grained details of agent interactions appropriate for informing future teaching agent design.

Interviews were used as part of the research method to provide answers to pre-set questions and to elicit elaborations on 'incidents' in the interactions that the researcher-observer found interesting. In the study, the researcher and interviewer (Cook) would take detailed notes, as a session progressed, of interactions that seemed interesting (e.g. interactions that seemed aimed at promoting metacognitive thinking). These notes were used as cues in the form of questions in the post-experimental interviews with the learners and the teacher. Ericsson and Simon (1993, p. xlix) have suggested that following the completion of a task, cueing distinct 'thought episodes' is a useful way to approach the gathering retrospective verbal reports. This involves constraining the retrospective report by the subject to the recall of distinct thought episodes. Post-experimental questioning runs the danger of allowing the subject to report more than their past thoughts, they might resort to speculation and inferences. However, using cues taken from the experiment can diminish this problem. Such a method would, it was hoped, provide aspects of the cognitive and metacognitive dimension of interacting agents, e.g. why did the teacher choose to make one intervention and not another, what knowledge and reasoning (internal dialogue) did the teacher employ when reaching a decision or adapting a plan to meet the user's needs?

4.2.2 Protocol transcription approach and reliability of data

Protocol transcription (coding) was based on the approach to Conversational Analysis used by Fox (1993). What follows is an almost verbatim description (from Fox) of parts of her approach, although in our analysis an utterance could be verbal, written or musical.

// indicate the place at which a speaker's utterance is overlapped by an utterance or act from another speaker. Utterances that are overlapped more than once have more than one double slash in them, and the utterances that do the overlapping are given in sequential order after the overlapped utterance.

[at the beginning of a line indicate that two utterances (the ones above and below the symbol) began simultaneously.

= indicate latching, that is the next speaker begins without the usual "beat" of silence after the current speaker finishes talking. In this case there is an equal sign at the end of the current speaker's utterance and another at the beginning of the next speaker's utterance.

=[indicate that the utterances above and below simultaneously latch (talk at once).

'[]' brackets with capitalised words enclosed represents non transcribed material (i.e. music or noises that are non-linguistic).

">" indicate rising, but not terminal rising, spoken intonation, as is often found at the end of each member of a list.

(0.8) numbers given in parentheses indicate elapsed silence, measured in tenths of a second. Only pauses of (0.9) upwards for reflection and (0.7) for 'complete' categories were recorded (Appendix 2 gives full definitions of categories). Punctuation is used to suggest intonation; italics indicate stress. A colon after a letter means that the sound represented by that letter is somewhat lengthened; a series of colons means that the sound is increasingly lengthened. The letter *h* within parentheses indicates 'explosive aspiration,' and usually means some type of laughter is being produced. A series of *hs* preceded by a dot represents an in breath. Questionable transcriptions are encoded within parentheses (i.e. it is not clear who made the utterance). Table 4.1 below gives an example of the transcription approach (see column 1).

Table 4.1

Example of coding†

Agent turn-utterance	Sub-goal (turn)	Act (utterance)	Other	Commentary and post-experimental cue data
TA1: And [17 MINUTES INTO SESSION, CLICKS ON COMPILE, THE LIST IS: 0 -5 7 0 28 2 2 1 24 -5 -4 -3 -2 12 6] compile button.		request	action	Comment: This is a self-request by the teacher for some action to be performed (i.e. to click on the compile button so that a midi-file palette is generated). As we are only using primary acts in the analysis this will suffice, but really this is an announce act.
TA2: Do you think that now that you've heard it a few times you would want to change the tempo? (6.1)	target M or Ref	question	poss. reflec-ting (LA)	Comment: The teacher is trying to get the learner to imagine or predict what would happen if the tempo was changed. The teacher leaves a 6.1 second pause, which is not accepted as an opportunity to speak by the learner (see interview data at LA6 for an indication of the learner's internal thoughts at this moment). This is close to a critical probing sub-goal as it uses the criteria of 'tempo' but the question is still open-ended and is therefore coded as 'target M or Ref'.
TA3: Is the tempo, satis//factory?	target M or Ref	question		Comment: The teacher prompts the learner with a rephrasing of the TA2 question. Transcription comment: // indicate an overlap utterance at LA4
LA4: Yeah, well, well // I'll hear it.		offer		Comment: The learner suggests that the way in which he would like to proceed is to hear the piece first. Transcription comment: // indicate an overlap utterance at TA5.
TA5: Lets hear it. [PLAYS PHRASE]		accept	action	Comment: The teacher accepts the learner's offer of the next step to take and clicks on play.

Table 4.1 (continued)

Agent turn-utterance	Sub-goal (turn)	Act (utterance)	Other	Commentary and post-experimental cue data
LA6: (9.07) I think, (1.3)	reflect imagine opportunity			Comment: These pauses are allocated to the category shown in the goal column on the basis of the context, i.e. in the next two utterances at LA7 & LA8, the learner attempts to satisfy the turn sub-goal of 'creative imagine opportunity'. The learner is therefore deemed to be reflecting about this opportunity in this turn. Post-experimental cue interview data: **The learner:** "Umm, soon as he said 'what about the tempo' I started considering different tempos, how it would sound with different tempos. And although my initial reaction [was] 'what do you mean by a tempo?', what was meant by that was: do you mean in terms of lengthening the phrase in parts. Now I just used the one full phrase and something that I normally do whether experiment, suddenly hearing that phrase but say twice as, lasting twice as long as before and that can have an impact as well. And I think in terms of my phrases, which were just plonked in very high, I think it would add to the impact of the surprise if they were suddenly long and sort of add to the suspense as well. So that's what I meant. And yes I considered, I thought at first when he said tempo I thought 'he's thinking that that I would like it slower', would I like it slower? And thought about it and my answer was that I actually think that it would be better faster."
LA7: depends whether you're talking about tempo across the whole thing?	creative imagine opportunity	question		Post-experimental cue interview data (this is what the teacher reports he was thinking when the learner made this, LA7, utterance): **The teacher:** "Well I evaluated that response as meaning are you talking, are you talking about the general tempo of the piece, or the tempo within particular sections, phrases in the piece. Umm, that's what it meant." Comment: The above data gives an indication of the teacher monitoring that occurs whilst the learner is talking. This represents the beliefs that the teacher has about the learner

Table 4.1 (continued)

Agent turn-utterance	Sub-goal (turn)	Act (utterance)	Other	Commentary and post-experimental cue data
LA8: If your gonna change tempo // try it, try it a bit quicker.	(LA7 goal still active)	request		Transcription comment: // indicate an overlap by the action at utterance TA10 (not shown). Comment: As the teacher would have had to reset the tempo in Coleridge himself the 'request' CA is correct in this context (it has a move function of a learner directive for teacher to do something).

† TA = Teaching Agent; LA = Learning Agent

An important point to note, about our approach to coding, is that an agent turn (intermediate sub-goal level) could potentially result in more than one category in a goal tree receiving a score. If more than one level in the hierarchies described in the above section on the KMf was involved in an agent's turn, then that turn (or part of that turn, i.e. a communicative act at the utterance level) received a score of 1 for each goal and act category involved. For example, if we were to code turn TA3 in Table 4.1, then the teaching agent would score as follows: 'target M or Ref' would receive a score of 1 and 'question' would also receive a score of 1.

If the occurrence of a turn (intermediate sub-goal level) was identified in the data, it was coded only once and a communicative act or action was also associated with that turn. The subsequent interactions that aimed to satisfy a turn sub-goal were coded as communicative acts only, until a new goal was encountered. Utterances LA7 and LA8 in Table 4.1 provide an example of this approach to coding. At LA7 'creative imagine opportunity' scores 1 and 'question' scores 1. At LA8, the 'creative imagine opportunity' turn sub-goal is still active and does not score, 'request' scores 1. Thus, if an agent's turn makes use of more than one communicative act (i.e. several utterances), then each individual act receives a score of 1.

The motivation goal was an exception to this rule (each occurrence as a turn received a score of 1 because the content of each utterance tended to be similar). This decision was taken based on the authors own intuitions. However, with respect to motivation encouragement (which is meant to keep the conversation moving smoothly, i.e. it serves a dialogue management function), this decision can be supported by drawing on Bunt's (1989) observation that

> "there is some evidence suggesting that dialogue control acts should perhaps not be treated as changing the speaker's and hearer's states in exactly the same way as factually-informative acts. In contrast with factually-informative acts, dialogue control acts only have a "local" function in a dialogue, losing their significance almost immediately after they have been performed." (Bunt, 1989, p. 70)

Turns that did not easily fit into one of the predetermined goal tree categories (i.e. the categories shown Tables A2.1 and A2.2 in Appendix 2) were coded 'other' (and a category was created that described the apparent function of the turn, e.g. 'incomplete utterance'). These 'other' categories represented adjustments that had to be made, once analysis had commenced, due to a poor fit between interaction data and the predetermined analysis categories (i.e. Tables A2.1 and A2.2 in Appendix 2).

If the interaction analysis described in this thesis were undertaken by another researcher, what would the score for intercoder reliability be? We have confidence that the score on this factor would show high reliability, this would make a good line for future research. However, in the context of this thesis we would point out the following. Psychology deals with dependent variables, thus the reliability of a coding scheme is important when treating some hypothesis related to the variables under study in the research. Linguistics research does not perform intercoder reliability checking, relying instead on the immersion of the investigator in the situation under investigation (e.g. the ethnographic method). But, within our approach the corpus plays a more suggestive role, it is used to inspire systems design. In this thesis we therefore avoided the need for intercoder checking by arguing for a user-centred system design approach. The condition under which this thesis was conducted can be used to support the previously made claim. For example, the author of this thesis was not the teacher being observed, we instead conducted the systematic observations and performed the interaction analysis. In the pilot study (Cook, 1994b) and in the empirical study reported in this thesis, learner and teacher perspectives on the interactions were elicited in interviews after a session by the use of the post-experimental cues technique. Also, the teacher was interviewed some months after the pilot study to confirm aspects of the interaction analysis in the pilot study (Cook, 1994b), this study was also used to inform the design of Coleridge and the KMf taxonomy. Furthermore, teachers and researchers played the role of co-evaluators in the formative evaluation of MetaMuse. Finally, in an attempt to at least make our own analysis inspectable, this thesis makes available a large amount of analysed interactions (in the main body and in the appendices). Our analysis is thus readily available for checking; indeed it has already been released into the public arena through conference papers and journal articles.

4.2.3 Data analysis software

HyperRESEARCH, a qualitative analysis software package, and various spreadsheets were used in the data analyses. The analyses of qualitative data (transcripts of the sessions) using computer-assisted methods generated quantitative data. Various approaches were used to analyse the data. These different approaches are described in Section 5.3.

4.3 Research approach and method for formative evaluation of the teaching agent (MetaMuse)

A fourth study (see Figure 1.1 in Section 1.5), which involved the computer-based teaching agent plus five users (four teachers and one researcher) in a formative evaluation setting, is described in Chapter 6 (Section 6.5). The research method used in the formative evaluation of the teaching agent (MetaMuse) was a questionnaire (described in Section 2 of Appendix 10) administered following a user's session with the teaching agent. The *aim* of the formative evaluation was to obtain feedback from music teachers and an educational technology researcher on various questions relating to the suitability of the teaching agent for use in higher education.

Evaluation can, however, be used to drive the design and specification of a system by testing intermediary versions which incorporate features of the design (i.e. as part of the iterative, user-centred systems design approach outlined at the beginning of this chapter). Cooperative Evaluation (Wright, Monk et al., 1990; Monk, Wright et al., 1993) was therefore used as the research approach in conjunction with a questionnaire (the research method) for the evaluation. Cooperative Evaluation is a system development approach that places emphasis on a user working through a task and answering such questions as: What will the system do if? What has the system done? Why has it done that? Other approaches to evaluation tend to regard users as experimental subjects. Cooperative Evaluation has already been used by this author to evaluate an Intelligent Tutoring System (Cook, 1991). The basic idea is to have typical users work through realistic tasks in order to identify usability problems, which can then be used to refine the prototype.

However, as was stated above, the *aim* of the evaluation was to obtain feedback from music teachers and educational technology researchers on a number of related questions (elicited via questionnaire). It should be noted that a full Cooperative Evaluation was not planned: we did not intend to analyse all the protocols gathered in order to identify 'incidents' of useability. Rather, we wished to gain evaluative feedback on the outcome of using the KMf to design and implement an agent (the outcome being the teaching agent). The data from this initial co-evaluation could potentially be used to inform the construction a full prototype teaching agent, which could then be evaluated with students (however, this is post-doctoral work).

In terms of evaluating the 'Teaching Knowledge Component' of any ITS or ILE, Mark and Greer (1993) suggest that the way forward is unclear (therefore we claim that the approach to evaluation adopted here would seem to be a reasonable one):

> "The standards to which teaching knowledge can be compared are instructional theory and the expert human teacher. Teaching knowledge is not necessarily well understood or explicitly

described, making it difficult to evaluate ... If standards for assessing the significance of an ITS's teaching knowledge were developed, they might reflect the NSTA [National Science Teachers Association] criteria, which includes specific considerations such as the range of instructional methods offered by a program, the degree to which a program can adapt its behaviour to individual differences of students, and more general concerns such as the degree to which instruction is based upon educational and psychological research in teaching. How such criteria could be assessed, formatively or summatively, is as yet unknown. Sensitivity analysis and certification might be possible approaches for investigation. Turing tests and experimental techniques are difficult to apply to an isolated tutoring component ... One possibility is to experimentally compare teaching knowledge components of an ITS, while keeping other components identical ...". (Mark and Greer, 1993, p. 139)

A possible alternative to Cooperative Evaluation would have been to use the approach being used by the SCILAB researchers at Leeds University (Hartley and Ravenscroft, 1993) and suggested at the end of the above quote by Mark and Greer. Both qualitative and quantitative data could have been gathered about student use of a prototype in a summative evaluation. Control studies could then be carried out using slightly different versions of the teaching agent prototype to try and isolate the effect of specific components on the learner. In the agent that was implemented (described in Chapter 6), preference for particular intermediate sub-goals could have been changed to see what observed effect this had on learning. This approach to evaluation may be useful for future work when a full prototype has been implemented.

4.4 Summary of research approach and methods

The research approach adopted in this thesis has involved one approach to what has been termed User Centered Systems Design. In this approach system design is based on empirical data and redesigns are based on empirical measurements of the success of the design, made on actual use of a prototype. The research methods that were used for the empirical study that formed the basis of the initial teaching agent design (i.e. the computational model) were a combination of complementary methods, involving systematic observation, post-experimental interviews, data transcription and qualitative data analysis to generate quantitative data. The research method used for the formative evaluation of the teaching agent was a questionnaire.

Chapter 5 - Analysis of Empirical Data

5.1 Introduction

This thesis has proposed a user-centred approach to designing computer-based teaching agents in problem-seeking domains. The design approach is based on a principled and systematic relationship between theory, analysis of empirical data, computational model and computational implementation. This chapter explores the second component of this design approach: the analysis of empirical data. Our theoretical framework was used to guide the analysis and modelling of data produced by an empirical study — which we describe below — of human teacher-learner interactions.

Following a review of the literature at the end of Section 2.1.1, it was concluded, that there is a need for studies that investigate how dialogue in higher education can assist musical creative reflection. What we are claiming is that we do not have available to us the precise details of the mechanisms of interactive learning in these problem-seeking domains. Furthermore, a small survey of music cognition and education experts (Appendix 1) gave this project the impetus to go on to conduct a detailed, and a new, study in this area (although of course we are only able to investigate a fraction of the story of metacognition in musical composition). Consequently, this chapter describes an empirical study that investigated the way in which a human teacher supported higher-order, musical thinking in learners[24]. The

[24]The initial findings of the empirical study were presented in a paper to be found in the proceedings for the AI-ED 97 (Kobé, Japan) conference (Cook, 1997c). A significantly extended version of the AI-ED 97 conference paper (which incorporates the KMf chapter and this chapter) has been published in the International Journal of Artificial Intelligence in Education (Cook, 1998). This journal paper was an "invited submission", solicited by the journal's editor given that a paper presented at the AI-ED 97 conference was judged, by the international panel of reviewers, to be one of the top 12 papers.

discovery of some connection between a mentoring intervention and learner creative reflection was hoped for.

The study involved four sessions. In each session a teacher and one student interacted with each other and a computer-based learning environment[25]. By using our theoretical framework derived from an extension of the literature (i.e. the KMf), the interaction analysis involved a categorisation of the study data (transcriptions of the sessions) into goals and communicative acts. Frequency counts were generated for each category. Further analyses of this categorised data generated various results.

The interaction analysis theoretical framework (the KMf described in Chapter 3) and the study described below are part of a teaching agent design approach that aims to make practical use of empirical research in teaching agent development. As we point out above, no empirical work has yet been reported in the area of mentoring, metacognition and musical composition in higher education. Therefore, an empirical study to inform the design of an artificial agent was conducted. The detailed results of such empirical work can, for example, be used to determine the weightings in preference mechanisms for making decisions about which intervention a computer-based teaching agent should make at a particular point in time (such an approach is described in Chapter 6).

5.2 The study materials and set-up

5.2.1 A learning environment for creative reflection: Coleridge.

In Section 1.3.2, a musical learning problem was identified, namely that some learners may have poor recall of a piece they have just composed (Morgan, 1992). This suggestive finding was supported by the post-experimental interview data shown in Table 5.1. The interview was conducted with the teacher in study 2 (see Figure 1.1 in Section 1.5), the pilot study (Cook, 1994b) for this thesis. In Figure 5.1 below, I = Interviewer (Cook) TA = Teacher. Bold text highlights the relevant part concerning memory and poorly developed recall of structure.

[25] i.e. Coleridge, this was built by Cook in collaboration with an experienced composer-teacher.

The teacher's comments in bold in Table 1.1 suggest that the learner's memory was not very well developed. On the basis of such considerations a computer-based learning environment called Coleridge (Cook and Morgan, 1998) was built. Coleridge was developed in collaboration with an experienced composer-teacher and was designed to provide the fast playback of musical ideas, thus (hopefully) freeing up time for interaction and metacognition. It was used in the study for this reason. Non-musical readers may wish to skip to the next sub-section; or use the glossary provided to help understanding of the musical terms used below. Coleridge was built in a Common Lisp based music composition language called Symbolic Composer (Morgan and Tolonen, 1995) and is a constrained environment in that it deals with only one small aspect of musical composition (the transformation of a musical pattern into a phrase or section). An annotated screen-shot of Coleridge is shown in Figure 5.1.

Table 5.1

Interview extract from pilot study (study 2)

I: You know task one where the student did the drawing that looked more or less like that [shows diagram made in own notes of learner's diagram].

TA: Yes.

I: Err, how did you evaluate ... the student's response to your teaching intervention.

TA: Their response to being asked to do the drawing?

I: Umm.

TA: Umm, I think my response was, I was very anxious to get clarity. For the students to be more clear about their own design. Umm, I actually wanted to, there is a desire in me to affect this clarity in order that their, that picture would have a more powerful effect. I found it was very difficult not to emm, I had to restrain myself from clarifying it too much, or imposing upon her the image that I've already got of that piece in my head. It was interesting that, in the two listenings she took what is in fact a two bar trombone solo break, as a major, as quite a large structural part. Which surprised me.

I: Umm, it's the way she heard it.

TA: The way she heard it. Err, and it was, I was a little taken aback by her first response. That's why I asked her to do the drawing. **And I was interested to see, when she was doing the drawing, that she was thinking very much in phrases rather than in section structures. Her memory, I was very conscious, that her memory was not very well developed in that respect.**

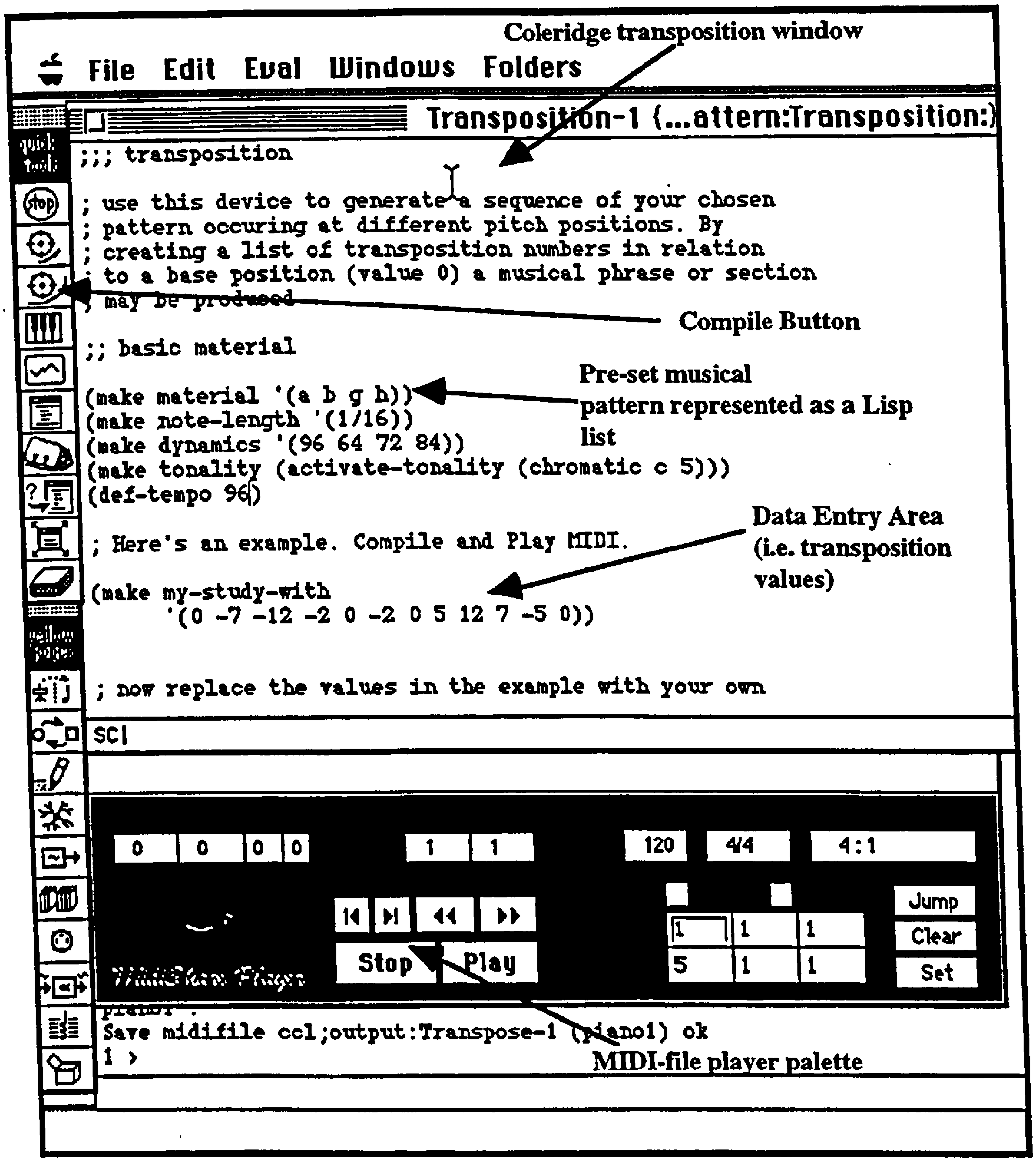

Figure 5.1. Annotated screen-shot of Coleridge.

The technique used in Coleridge for transposing a pre-set musical pattern (C C# F# G is initially given in the form of the Lisp list 'a b g h') is simply to use a transposition number (which represent semi-tone steps, i.e. chromatic pitch transposition). By creating a list of transposition numbers in relation to a base position (value 0) a musical phrase or section may be produced. Zero in the list (i.e. the data entry area shown in Figure 5.1) will simply give a repetition of the pre-set pattern (i.e. C C# F# G), -7 transposes the pre-set pattern down a fifth (i.e. it produces F F# B C), -12 plays the whole pattern an octave lower, and so on. The 'MIDI-file player palette' shown in Figure 5.1 can be generated for a list of transposition numbers by clicking on the 'Compile Button'. Compiling a list thus produces a phrase or section ready for playback. Compiling and playing the list '0 -7' would produce the phrase C C# F# G F F# B C.

5.2.2 The study.

The study took place at a British University College in November 1996. The aim of the study was to answer the following research question: *what are the interactive means by which a music composition teacher stimulates creative reflection?* Four teacher-learner sessions were conducted with four third year BA Combined Studies students (each of who were taking a music specialism). Three students were male and one female. Each learner-teacher session lasted about 30 minutes and was recorded on two video cameras and Dictaphone. One camera focused on the computer monitor and the second camera had a 'good' microphone attached and was pointed at the study participants. The Dictaphone was used as it aids the speedy transcription of study dialogues. Teacher and student sat in front of a composer workstation, which consisted of a Macintosh PowerPC with Coleridge installed, an electronic keyboard and a mixing desk attached to speakers. The four students were selected by the composition lecturer. The students and teacher gave their help free of charge. The learners were interviewed immediately after a session for 10 to 15 minutes. The teacher was then interviewed for 10 to 15 minutes. The following instructions were given to the teacher a few weeks before the session:

> Please interact with the students for 30 minutes and try to promote the learning outcome of creative reflection by using a process of mentoring. The interactions should assist the learner in the process of problem-seeking. Use the task described below and Coleridge as the basis for interaction with the students.

The teacher was familiar with these terms but was nevertheless given definitions. (See Appendix 3 for a detailed description of the materials used in the study, which includes details of the instructions and definitions given to the teacher in Section 2.)

The task was to ask the learner to generate, by transposition of a 4 note pre-set pattern, a musical phrase (specifically chromatic transformation of the pattern). Slonimsky (1947) pattern No 1 , which is C C# F# G, was given by Coleridge at first. No alteration of the rhythm was allowed (although such a possibility could be discussed). The overall tutorial task goal was 'reflecting on the inner structure of a musical pattern'. There were three task sub-goals associated with the overall tutorial task goal: for the teacher to elicit an example of structural content from the learner's phrase, second to critically analyse (jointly) the phrase, and finally that of encouraging the learner to place this phrase in the context of a whole musical section.

The following goals were involved in the study. The teacher intended to promote learner creative reflection by using mentoring pedagogical goals. The learner would, it was hoped, accept the task goals and other goals related to mentoring; the learner would then go on to make attempts at creative reflection. The discovery of some causal link between a mentoring intervention and learner creative reflection was hoped for.

In post-experimental interviews the teacher and three of the four learners said that they did not feel that the observation setting had exerted an undue influence on their behaviour. However, learner 2 reported that he did feel that the observation setting had exerted an undue influence on him. Given this suggestive evidence, it is assumed that the corpus collected was a reliable record of teacher-learner interactions. The students normally received composition tuition on a one-to-one basis (often in the room where the study took place) and the sessions observed will not have been too unusual for them. However, this must be weighed against the knowledge that being observed will tend to exert some change of behaviour on the object of observation.

Approximately two hours of teacher-learner interactions were transcribed (using the approach described in Section 4.2) and analysed using the approach described in the next section. One and a half hours of post-experimental interview data was also transcribed and extracts incorporated into analysis four (which is described below).

5.3 Analysis

The empirical work involved seven detailed analyses of the corpus collected in the study described in the section above. By using a framework derived from the literature (the KMf described in Chapter 3), the first interaction analysis entailed a categorisation of the study data (transcriptions of the sessions) into intermediate level sub-goals and communicative acts. Frequency counts were generated for each category. Further analyses of this categorised data generated various results. Each of the (interlinked) analysis types are now described below.

5.3.1 First analysis, quantitative results from qualitative data.

The aim of this analysis was to identify the extent to which different mentoring goals and sub-goals were pursued. In the first analysis, interaction data from the four sessions was analysed using the approach described above in the research methods section (Section 4.2). The only categories coded were sub-goals at the intermediate level (turns) and communicative acts (at the utterance level, see Figures 3.1 and 3.2). The above section (3.1) described these categories. Appendix 2 provides a summary of all the goal, sub-goal and communicative act categories used in the interaction analysis. Quantitative counts of the total number of occurrences of each category in the qualitative interaction data were generated by analysis one.

5.3.2 Second analysis, steps leading to learner creative reflection.

The second analysis involved an examination of two important learning agent sub-goals (chosen because they relate to creative reflection): 'creative imagine opportunity' and 'monitoring diagnose'. The categorised data produced by analysis one was re-analysed to locate each occurrence in the data of these two important learning sub-goals. For each occurrence of these sub-goals in the data, we backtracked through the categorised data to the 6th utterances (this was an arbitrary choice thought sufficient to identify some recurring patterns) preceding the occurrences of these important learning sub-goals. Note that we excluded 'actions' from this analysis, except for data entry into Coleridge by the learner. Teaching interventions in these '6 utterance chunks' were then analysed in an attempt to detect any recurring patterns, *i.e., common teacher intervention(s) that may have lead to either learner 'creative imagine opportunity' or learner 'monitoring diagnose', or both.*

5.3.3 Third analysis, learner activity leading to all teacher responses.

The third analysis of data examined teacher interventions to ascertain which learner intermediate sub-goal or communicative act preceded it. It was hoped that such an analysis would throw light on the secondary research question: Given a particular student intervention, what are the common forms of teacher responses? This third analysis involved an examination of all teacher turn sub-goals and communicative acts (of the categorised data produced by analysis one), and then stepping back through the analysed data to find the first occurrence of a learner turn and/or act. If an act was associated with a turn (e.g. 'question' associated to 'critical probing') only the turn sub-goal was recorded (in the previous example 'critical probing'). This relationship was then recorded on a spreadsheet (i.e. learner intervention X leading to teacher response Y would increment by 1 the cell XY). Learner utterances and actions that lead to a teacher intervention can be seen as providing detail of the exact way in which a teacher adaptively promotes creative reflection. (Section 1 of Appendix 5 gives more detail of this third analysis approach.)

5.3.4 Fourth analysis, post-experimental cue data.

In the fourth analysis, post-experimental cue data was incorporated into the interaction data (the categorised data produced by analysis one) in an attempt to enhance the analysis (i.e. to include the cognitive and metacognitive dimension of the interacting agents). For a discussion of cue data see Section 4.2. Various large interaction extracts were analysed using this analysis approach, a small example of which is provided in Table 4.1 (in Section 4.2) at LA6 and LA7.

5.3.5 Fifth Analysis, mentoring stages.

Analyses one to four provided considerable detail of interactions from a micro-level. The fifth analysis attempted to pull out a macro view of interactions (of the categorised data produced by analysis one). The turn sub-goals (communicative acts were excluded from this analysis) for each session were analysed to see if any patterns or stages within a session could be detected.

5.3.6 Sixth Analysis, state transition networks.

The sixth analysis involved the mapping of various state transition networks to represent the sequence in which goals and sub-goals were pursued in interactions. Analysis six took as its starting point the result from analysis five (i.e. the seven mentoring stages, discussed in the results section below).

Winograd and Flores (1986, pp. 64) demonstrate an approach to representing networks of speech acts which they call 'conversations for action'. As was pointed out in Section 2.3.2, state transition networks can form the basis for computer tools (Winograd, 1987-1988) and thus form a useful approach, which has been adapted here to meet the analysis needs of our research. The approach provides a formal representation of the interplay between speech-act illocutionary point (Searle, 1976) 'directives' (in KMf questions and requests) and speech-act 'commissives' (in KMf offer, accept and accept-confirm) that are directed towards some explicit cooperative, teaching action. It is important to note that the networks presented below are descriptive, not normative, as were Winograd's (Winograd and Flores, 1986)[26].

In the state transition networks (see the illustrative example in Figure 5.2) the

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[26]However, when implementing MetaMuse these networks started to become more normative and prescriptive as they incorporated numerical weightings in the decision mechanism.

course of an interaction can be plotted using circles to represent a possible state of the agent interactions, and lines to represent goals and communicative acts (Winograd and Flores only represent acts). The diagrams do not represent a model of the mental state of a speaker or hearer, but show the interactions as a 'dance' between agents using acts or sub-goals to achieve a goal. The lines indicate goals and communicative acts that can be taken by the teaching agent (TA) and the learning agent (LA). Each act in turn leads to a different state, with its own space of possibilities. So for example, in Figure 5.2, the teacher may have made an 'offer' of how to proceed or some 'request' regarding a task goal (the arrow from A to B). In the normal course of events, the learner (LA) 'accepts' the teacher's 'offer/request' regarding a task goal (perhaps performing some 'action' and moving to the state labelled C in Figure 5.2). If the teacher declares satisfaction with the act 'accept confirm', the interaction episode reaches a successful completion and both agents reach state D.

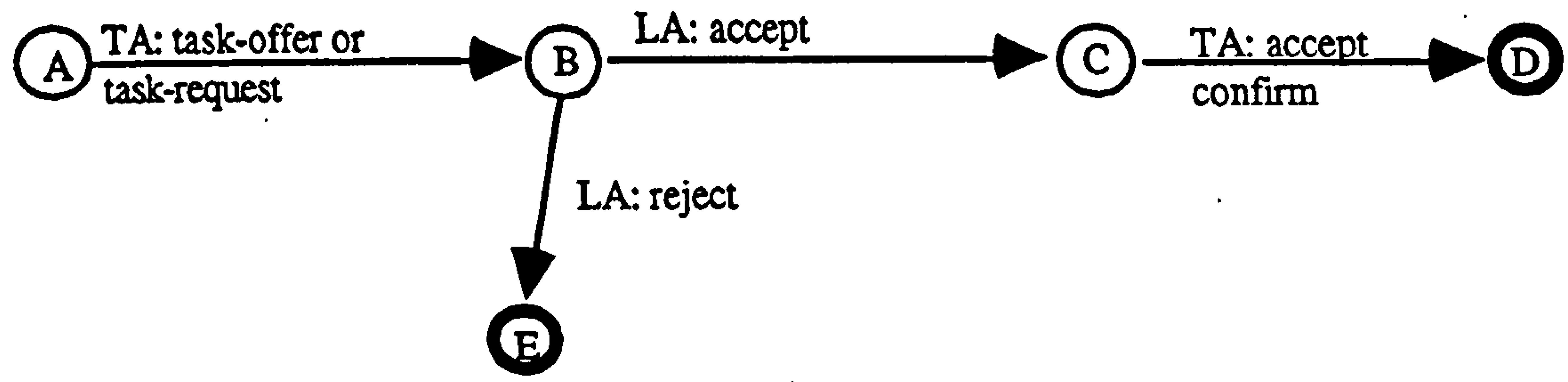

Figure 5.2. Illustrative network of acts.

However, at state B the learner may 'reject' the offer or a request made by the teacher. There are a few states of completion from which no further actions can be taken (these are the heavy circles in Figure 5.2). All other states represent an incomplete interaction. Completion does not guarantee satisfaction, for example if the 'offer' is 'rejected' at state B by the learner in Figure 5.2.

5.3.7 Seventh analysis, mentoring script.

By drawing on empirical data from some of the earlier analyses, this analysis attempted to generate a script (Schank and Abelson, 1977) of the most frequent interactions. A script is defined here as an interaction sequence that is likely to happen (the script result is presented below in the next section). A script is presented as a series of intermediate level sub-goals (a turn) or communicative acts, with each agent taking turns. A likelihood can be defined as "The chances of successful achievement of a goal" (Slade, 1994, p. 60). The likelihood of a goal occurring is given as a percentage score (where 0% = lowest likelihood and 100% = highest likelihood). The scores were derived from analyses 1 to 3.

5.4 Results and findings

A brief discussion of some general findings is given below. Four main results are then reported and discussed in detail. The four main results were a pause taxonomy, reciprocal modelling, seven distinct mentoring stages (with associated state transition networks), and a script of the most frequent mentoring interactions.

5.4.1 General findings.

The scores in Tables 5.2 and 5.3 below were generated by analysis 1 and show the total occurrences of a category for all four sessions. The score for one category is split between that gained for the learner (shown in the LA column), that gained for the teacher (shown in the TA column) and the total occurrences for that category for all four sessions (the total column).

5.4.1.1 Findings from analysis one

Some general findings (from *analysis one*) relating to the interactive means by which the teacher attempted to support creative reflection can be reported.

Some attempts were made by learners at 'creative imagine opportunity' (score = 26, Table 5.2). The mentoring approach taken and the support given by Coleridge appears to have encouraged some learner creativity. Students did not seem able to make accurate predictions, in spite of teacher support and a computer environment design to assist this process. The students did make some attempts at making a prediction; Table 5.2 shows 9 attempts by the learners at 'creative make prediction'. However, Table 5.2 also shows that only 1 out of 4 learners met with success at 'creative accurate prediction'. One possible reason for this may be that, because this form of creative reflection training was new to the students, it was only by the end of the 30 minute sessions that the students had become accustomed to the idea of going-above their own thinking and making predictions (i.e. the regulation-of cognition in the form of planning and predictions).

Table 5.2[†]

Mentoring sub-goals occurrence scores

Goal and sub-goal (turn)	LA	TA	total
Creative thinking			
creative imagine opportunity	26	13	39
creative make prediction	9	6	15
creative accurate prediction	1	2	3
Metacognitive intervention			
target M or Ref	1	29	30
Metacognitive thinking			
monitoring evaluate	40	3	43
monitoring diagnose	12	1	13
reflect predict	4	0	4
reflect imagine opportunity	8	1	9
Critical thinking			
critical judgement	2	28	30
critical probing	0	44	44
critical challenging	0	3	3
critical clarification	25	4	29
critical give reasons	9	3	12
critical give evidence	2	2	4
Motivation			
motivation intrinsic	0	11	11
motivation extrinsic	0	4	4
motivation encouragement	7	70	77
Task goals			
task	8	43	51

[†] TA = Teaching Agent and LA = Learning Agent

Table 5.3[†]

Communicative acts, relations and other occurrence scores

Utterance	LA	TA	total
Communicative Acts			
assertion	243	237	480
assertion confirmation	106	186	292
question	41	150	191
request	11	62	73
offer	6	71	77
offer continue	2	34	36
accept	51	28	79
accept confirm	20	3	23
reject	3	5	8
Relations			
complete	11	0	11
transform	0	9	9
Other			
pause critical	22	—	22
action	87	344	431
no category obvious	—	—	18
continuation	—	—	17
dialogue management	20	23	43
incomplete utterance	37	35	72
not accept yet LA	13	—	13
pause monitoring	29	—	29
retraction	1	—	1

[†] TA = Teaching Agent and LA = Learning Agent

A popular teacher intervention was 'target M or Ref'; Table 5.2 shows that it was used on 29 occasions. 'Target M or Ref' is an attempt to get the learner to accept a goal and pursue it, e.g. to get the learner to give an explanation by pursuing the goal 'monitoring evaluate'.

Some internalised self-monitoring took place. The interaction analysis approach recognises two metacognitive thinking sub-goals that were related to monitoring. 'Monitoring evaluate' was dialogue that involved some evaluative comment by the learner about the match between a prediction and an outcome (score = 40, Table 5.2). 'Monitoring diagnose' was an attempt by the learner to diagnose why something did or did not work (score = 12, Table 5.2). Table 5.3 shows that there were 29 occasions that were coded as 'pause monitoring' (which is where the context strongly suggests that pauses are indicative of learner metacognitive activity related to monitoring). These finding are encouraging in that the mentoring approach seems to have promoted the monitoring effect, which we would claim is the first step towards creative reflection, and in particular the ability to make accurate predictions.

The results show that the two most frequently used teaching interventions related to critical thinking were 'critical probing' (score = 44 for the teacher, zero for the learner, Table 5.2) and 'critical judgement' (score = 28 for the teacher, 2 for the learner, Table 5.2). Learner critical thinking involved 'critical clarification' and 'critical give reasons', which Table 5.2 shows occurred 25 and 9 times respectively. Interaction relating to critical thinking appeared to be teacher led. The teacher would initiate such a pedagogical goal with say a 'critical give evidence' turn sub-goal and related 'question' communicative act. The learner would typically respond with a 'critical clarification' turn and related 'assertion' communicative act. Thus, some goals belong exclusively to certain agents (e.g. 'critical probing' was only used by the teacher) and others belong almost exclusively to one agent (e.g. 'critical clarification' was used by the learner on 25 occasions but by the teacher only on 4 occasions). 'Critical give evidence' was used by both agents on 2 occasions each.

'Action' (one of the 'other' turn categories in Table 5.3) is where an agent plays music on a keyboard, uses the mouse to point to something under discussion on the screen or to click on an icon, it excludes all action performed by the computer (e.g. displaying a window). With a score of 344 'actions' (Table 5.3) the teacher was clearly very active and with 87 'actions' (Table 5.3) the learner was certainly busy. At face value the teacher may be open to criticism for not letting the learner be more active (there is an imbalance in the scores). However, it has to be said that music, like sports, is a coaching-like subject and the coach-teacher-mentor may tend to automatically reinforce what they are saying with musical actions (e.g. playing a motive whilst discussing it). By re-analysing all 'actions' it became apparent that the teacher was making many musical actions (i.e., either playing back a musical phrase on Coleridge, playing at the keyboard, singing or humming). The teacher made a total of 109 musical 'actions' in all four sessions (i.e. 31.6% of all teacher actions were musical).

The total number of teaching goal interventions by the teacher is the sum of the TA column in Table 5.2 (excluding motivation encouragement, which is seen as part of dialogue control). The total number of teacher goal interventions was 197. The total number of goal interventions by the learner is the sum of the LA column in Table 5.2 (again, excluding motivation encouragement, which is seen as part of dialogue control), plus the scores for 'pause critical' and 'pause monitoring' in Table 5.3 (these are 'other' categories, which means they were added after analysis was started). The total number of learner goal interventions was 198. Thus the total goal scores for teacher and learner were roughly the same. However, the categories of goals used by teacher and learner were, as we have seen above, different. For example, the learner's total includes a pause score of 63, whereas the teacher scored only one pause. This highlights the fact that a teacher's utterance nearly always selects the learner as next speaker, pauses in mentoring tend therefore to belong to the learner. Appendix 4 reports some more detailed findings from analysis 1 that are not reported in the main body of this thesis.

5.4.1.2 Findings from analysis two

Some general findings relating to *analysis two* can be reported, some of which are summarised in Table 5.4. Specifically, the means used by the teacher to promote 'creative imagine opportunity' were (mostly) 'target M or Ref'. Table 5.4 shows that it was found that: (i) 16 out of 26 occurrences of 'creative imagine opportunity' had in the previous six utterances the sub-goal 'target M or Ref' by the teacher, and that (ii) 11 out of 26 occurrences of 'creative imagine opportunity' had in the previous six utterances the combination 'target M or Ref' by the teacher and 'monitoring' of either type by the learner, and that (iii) 9 out of 26 occurrences of 'creative imagine opportunity' had in the previous six utterances the sub-goal sequence 'target M or Ref' by the teacher followed by 'monitoring' by the learner.

Table 5.4

Analysis of six utterance 'chunks'

learner 'creative imagine opportunity' (score = 26) was preceded by:	score
teacher 'target M or Ref'	16
teacher 'target M or Ref' plus learner 'monitoring'	11
teacher 'target M or Ref' THEN learner 'monitoring'	9
learner 'monitoring diagnose' (score = 12) was preceded by:	score
teacher 'target M or Ref'	4
teacher 'question'	4
learner 'monitoring evaluate'	6

Other less common variations included the use of the critical goals that led to 'creative imagine opportunity'. In particular, 'critical probing' by the teacher, in combination with 'target M or Ref' eventually led to the only occurrence of 'creative accurate prediction' identified in the analysis.

Furthermore, Table 5.4 also shows that it was found that: (i) 4 out of 12 occurrences of 'monitoring diagnose' had 'target M or Ref' preceding it, and that (ii) another 4 out of 12 occurrences of 'monitoring diagnose' had the 'question' communicative acts on its own preceding it, and that (iii) 6 out of the 12 occurrences of 'monitoring diagnose' were preceded by 'monitoring evaluate' by the student.

Analysis two indicates that students seem to perform monitoring before they imagine a creative opportunity. Some heuristics emerged from analysis two. 'Critical probing' was the teacher's most often used interactive goal (score in Table 5.2 = 44). 'Critical probing' was not only used as an intervention for eliciting an accurate prediction from one learner, it was also used if the learner was not responding with monitoring and creative like utterances (i.e. as a repair strategy). Striking the right balance between the more open-ended 'target M or Ref' questions (which leave space for a learner to integrate new knowledge with existing knowledge for themselves) and the more precise 'critical probing' (which gives direction on how the learner may integrate new knowledge by making reference perhaps to some propositional content) will depend on the student and the task involved. Clearly it will also depend on the teacher's own preferences[27].

5.4.2 Pause taxonomy result and discussion.

The major result of analysis one was a pause taxonomy, which is shown in Figure 5.3. A pause is usually a silence (the absence of vocalisation or musical acts); however, there were four occasions that were coded as pauses but where there was no silences (these pauses contained an 'emm' or 'err'). Pauses of 9 tenths of a second upwards were coded. A pause may indicate that the learner is simply having a rest or staring out of the window. However, a pause may indicate something else: pauses may have functions and different pauses may have different functions. **This research identified four categories of pauses** (a turn was allocated to one of these on the basis of the interaction context, see LA6 in Table 4.1 or Section 4.2 for an example). The first pause type, *reflect imagine opportunity,* which happen before or during communicative acts related to the 'creative imagine opportunity' intermediate sub-goal (score = 8). These are either silences or utterances like 'umm', where the learner reflects about an opportunity before actually using a communicative act to state what

[27]Although only one teacher was used in the study, we argue that this is a useful starting point for implementation, refinement and generalisation.

that opportunity was.

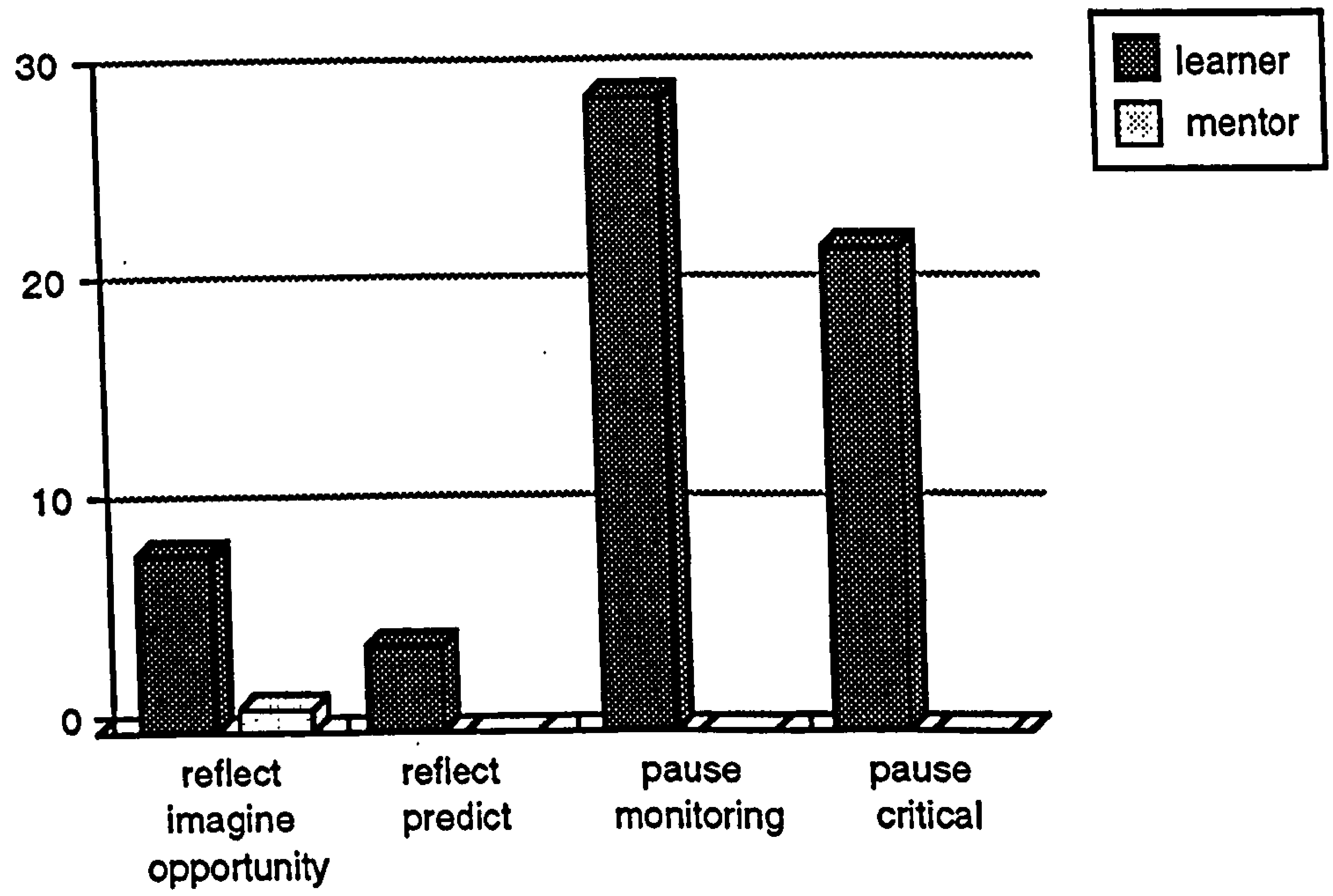

Figure 5.3. Pause taxonomy scores

The second pause type was *reflect predict,* which happen before or during communicative acts related to 'creative make prediction' or 'creative accurate prediction' intermediate sub-goals (score = 4). Third was *pause monitoring* (score = 29) which was associated with communicative acts indicating monitoring activity by the learner, or a pause left by the teacher (for the learner to reflect in) when making a 'target M or Ref' intervention (the latter happened on six occasions). The fourth pause type was *pause critical,* was related to communicative acts by a learner intending to achieve critical goals (score = 22). If we tabulate the occurrences of pause type by student, we get the results shown in Table 5.5.

Table 5.5

Student pause scores by pause type

student	reflect imagine opportunity	reflect predict	pause monitoring	pause critical	total
student 1	5	3	10	10	28
student 2	0	0	3	4	7
student 3	2	1	9	7	19
student 4	1	0	7	1	9
Total	8	4	29	22	63

Table 5.5 provides suggestive evidence of a link between pause length and learner ability. At the time of the study the teacher commented that he rated the first student highly and that he thought he would go far professionally (subsequently, in July 1997, student 1 was the only one of the four students in the study to obtain a first class honours degree). The teacher rated the second student as one of the weakest. In post experimental interview the teacher made the following comment about student 2:

> **Teacher:** I mean he is very good with purely sonic material, but he is very weak in, if you like, in the pitch domain. And he confirmed that with this exercise. Although what it did show is that in fact [student 2] really needs to do, to work at this level.

The above teacher assessment about students 1 and 2 are matched by the total pause scores in Table 5.5. Student 1, assessed as the strongest by the teacher, also received the top total pause score (28). Student 1 appears stronger at the creative thinking related pauses ('reflect imagine opportunity' score = 5, 'reflect predict' score = 3). In contrast, student 2 achieves the lowest total pause score (7) and spends no time on pauses related to creative thinking. An interesting line of future work would be to confirm the role of pauses in creative tasks.. If this tentative result was confirmed then this approach would be appropriate for computer-based assessment of learner progress in creative thinking tasks. One caveat is that although student 3 was the only student to make an accurate prediction, she did not achieve the highest pause score. However, her total pause score was the second highest. Further results relating to pauses that are not given in the main body of this thesis are reported in Section 6 of Appendix 4.

The pause taxonomy presented above may be at odds with the conception of a pause used by others. Brown and Yule (1983) use a pause as boundary indicators for a discourse analysis unit. The use of a pause as a boundary unit was used by Ng and Bereiter (1995) in a study of different levels of goal orientation in learning. Levinson (1983, p. 299-300) describes a system where a pause is used as a general cover term for the various periods of non-speech. The term silence (the absence of vocalisation) is used in a technical sense and assigned to a category, depending on rules of turn taking, of either: a gap, which is not attributable to any party by the turn taking system (e.g. the current speaker has not selected the next speaker, the silence therefore belongs to no one); a lapse (which tend to be longer gaps); or a next speaker's significant (or attributable) silence. The following example has two examples of attributable silence due to the fact that A's utterances select B as next speaker according to the rules of turn taking:

A: Is there something bothering you or not?

=> (1.0)

A. Yes or no

=> (1.5)

A. Eh?

B: No.

From Levinson (1983, p. 299-300)

The pauses identified in our taxonomy (Figure 5.3) are all attributable types, but of a more fine-grained nature than Levinson's. In human-machine studies a pause may be seen as breaking contact. In work on impasse learning a pause may be seen as indicating that a learner is having a problem. Fox (1993) sees a pause following a question as indicative of a student impasse:

> "Timing is also used as a metric of understanding in cases where the tutor is more explicitly eliciting information from the student, as with a question. The length of time the student takes to answer, in addition of course to what he or she is doing during that time, gives the tutor subtle cues as to how easily the student is able to answer. If the student stares blankly for 1 or 2 seconds, the tutor is almost certain to intervene with a hint, or another question; if the student appears to be "working on it," the tutor is likely to give him or her leeway until either the correct answer is achieved or the student gets stuck." (Fox, 1993, p. 72)

A student may well be in trouble if they stare blankly for 1 or 2 seconds. However, in our study the 'good' student (student 1) paused 5 times when reflecting on a creative opportunity, and achieved an average pause length of 8.37 seconds (average taken from results presented Table A4.3 in Appendix 4, Section 6). The outcome of the task for student 1 was described as successful by the teacher (in post-experimental interview comments about the learner's composition). Fox suggests that subtle cues can help interpret the meaning of pauses. However, what the (tentative) empirical finding of this study may imply is that longer or more frequent pauses on certain tasks may be desirable.

5.4.3 Reciprocal modelling result and discussion.

Analysis four found that reciprocal modelling (where participants in learning interactions build up models of the other participants' expectations) may be more important in creative learning activities than has been so far recognised. The interview data (taken from analysis four) at LA6 in Table 4.1 (Section 4.2) shows that the learner brings into his considerations 'what he thinks the teacher might be expecting him to do', i.e. the student is building up a model of the teacher's expectations. This was also found in session 4 and is what Dillenbourg (1993, p. 2) called reciprocal modelling and Bunt (1989) calls partner modelling. In the example given in Table 4.1, once the teacher's expectations have been inferred by the learner (i.e. beliefs about a partner's beliefs), the approach seems to be one of trying confound those expectations, to surprise. This is evidenced at LA8 (Table 4.1) where the learner suggests that the tempo could be "quicker", the opposite of what the learner believes the teacher wants him to do. The teacher appears to value such activity. In the interview data associated with TA15 (not shown in Table 4.1) the teacher comments about the learner's large interval leaps:

> **Teacher:** He did something that I just didn't expect. Which is a very healthy sign in any composer, prepared to take those sort of risks.

This tells us something about what the teacher values from his students, i.e. novelty, surprise, etc., and that his model of the learner indicates that he believes the learner has committed to this value. Of course, not all teachers will value the same thing and surprises have to be the right kind of surprises.

Partner modelling was identified as occurring once in 2 out of 4 of the sessions using the post-experimental cue technique. Partner modelling may have happened in all four sessions, a question (in post-experimental interview) that would have ascertained this was simply not asked in 2 cases. In one instance the learner had a goal of causing surprise:

> (Session 1 example)
>
> **Learner:** I thought at first, when he said tempo, I thought 'he's thinking that I would like it slower', would I like it slower? And thought about it, and my answer was that I actually think that it would be better faster.

In session four the learner's goal was to do what was expected of him, but with an increased intensity

(Session 4 example)

Learner: So now when [the teacher] says: 'Make it more irregular', I go out of my way to make it more irregular.

The first session was deemed by the teacher as more successful than the fourth, possibly because he valued surprise. One implication for teaching is that learners should not be allowed to become too entrenched in reacting on the basis of one partner model. It is the author's feeling that, although the student in session 4 was very capable and indeed outspoken, his stated goal of going "out of my way to make it more irregular" may have been counter-productive. Session 4 accounted for all 13 occurrences of 'not accept yet' shown in Table 5.3, which is where the learner does not appear to accept the validity of the tutorial 'task' or 'offers' made by the teacher on how to proceed in the session. (Appendix 6 gives three extended examples of analysis approach 4.)

5.4.4 Seven stages of mentoring result and discussion.

Table 5.6, a result from the fifth analysis, shows that there was evidence for seven mentoring stages (in the order shown) in most of the sessions. The symbol 'x' in the session column means that the stage indicated by the associated row was identified in that session. The symbol '-' means that a stage was not identified for that session.

Table 5.6

Seven stages of mentoring

Stage	Purpose	Session 1	2	3	4
1. Open session with extrinsic motivation.	Influence learner's affective response to session	x	-	x	x
2. Introduce task and initial probing	Making sure that the task is understood.	x	x	x	x
3. Initial use of Target M or Ref	Promoting monitoring and 'creative imagine opportunity'.	x	x	x	x
4. Teacher led critical thinking using probing and judgement	Giving direction on how to give predictions and imagined opportunities.	x	x	x	x
5. Target M or Ref used (iterate 3-4 times)	Leaving space for the learner to give predictions and imagined opportunities.	x	x	x	x
6. Return to Teacher probing	Getting 'accurate prediction' (if not already achieved) or more 'creative imagine opportunity'.	x	x	-	x
7. End session.		x	x	x	x

In analysis five, print-outs of the goals (communicative acts were excluded) identified by analysis 1, for each session, were analysed to see if any sequence or clusters of goal-types could be detected within a session. All analysis was done by hand because the qualitative analysis software package used did not provide easy list manipulation or text export facilities. Initially 10 stages were identified, however, because 3 of these stages were identified as only occurring in two or less of the four sessions, they were excluded from the stages shown in Table 5.6. The mentoring stages result represents an empirically based plan for a mentoring session, with the purpose column in Table 5.6 giving preferences for particular intermediate goals that were identified as being used in that stage. A detailed presentation of the goals that were and were not identified in each stage, for each session, can be found in the Appendix 7 (Table A7.1).

Since a detailed elaboration of these seven mentoring stages could prove an invaluable resource to a computer-based teaching agent, analysis six included an in-depth exploration of each stage. State transition networks have been generated for all seven stages of mentoring identified in analysis five (Table 5.6). Unlike the goals used to achieve transitions in mentoring stages 1 and 7 (i.e. open session and end session), which are relatively simple, the networks for mentoring stages 2 to 6 are more complicated. The seven state transition networks are all empirically derived (i.e. they represent all the goals identified by analysis 1, with a few exceptions that are noted). Thus, the seven networks describe the goals and sub-goals identified in the interaction analysis. That is to say, the sequencing of goals identified in analysis 1 (for all four sessions) is directly represented in the networks

To illustrate the approach, the network for mentoring stage 3 is given in Figure 5.4 (all seven networks and associated discussions are available in Appendix 8). The network shown in Figure 5.4 covers all the goals observed in sessions 1 to 4 for the third mentoring stage (i.e. initial use of target M or Ref) with the minor provisos that, although occasionally a goal is repeated in the interaction data, this is not represented in the network. In session 1 the final state was 12, in session 2 this stage ended quickly at state 10, in session 3 the final state was 19, and in session 4 the final state was 16. The entry points to the network shown in Figure 5.4 could be either node 6 or 8.

A common goal sequence was identified in stage 3, i.e. 'target M or Ref' (state transition 8 -> 9 in Figure 5.4) leading to 'monitoring evaluate' (9 -> 10) then 'monitoring diagnose' (10 -> 11). This goal sequence was also identified in analysis 2 (see discussion in sub-section '5.4.1 General findings'), and was also evident in mentoring stage 5 (which is given in Appendix 8, Section 2.5).

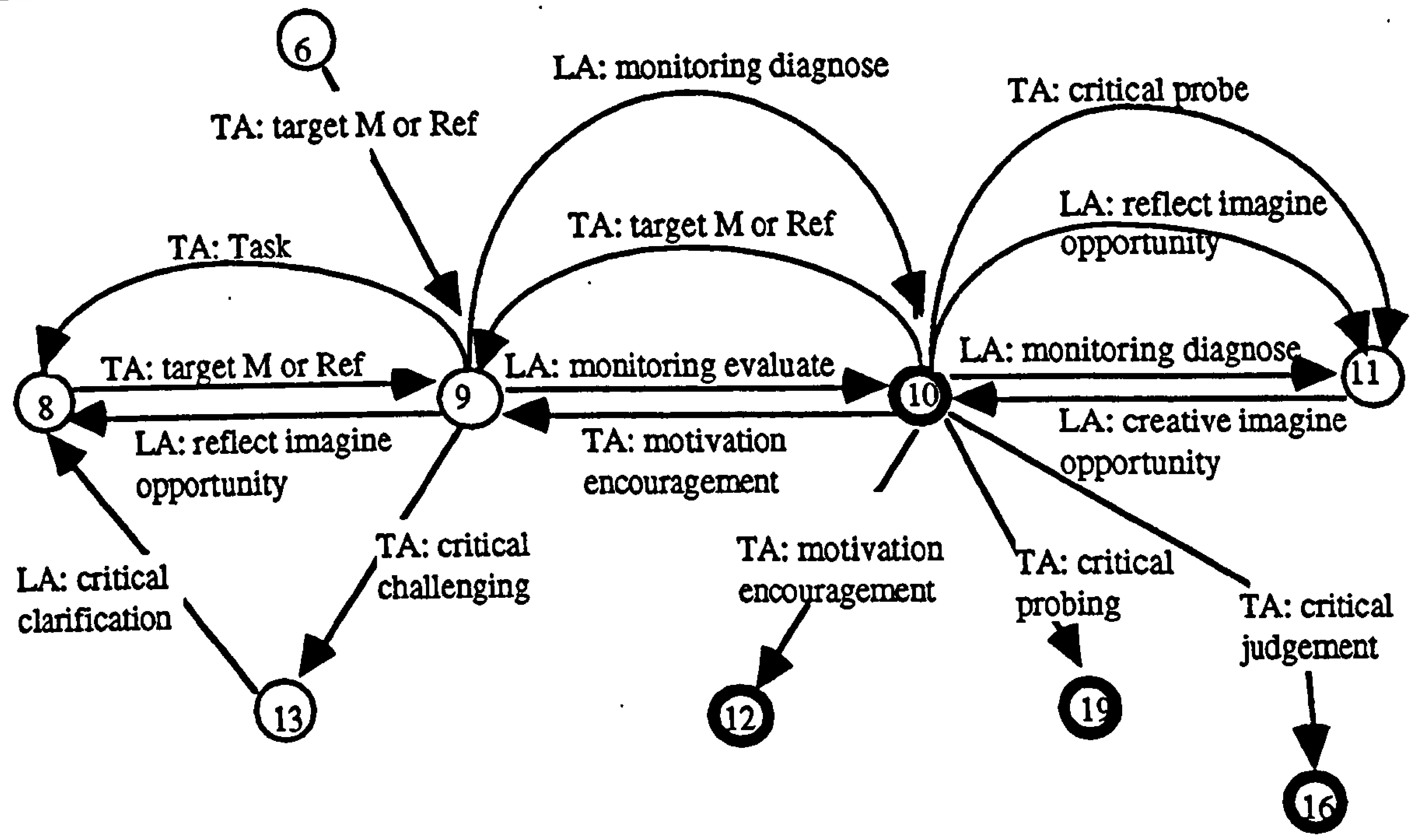

Figure 5.4.[†] Mentoring stage 3 network: 'initial use of target M or Ref'

[†] TA = Teaching Agent and LA = Learning Agent

5.4.5 Mentoring script result and discussion.

Note that in analysis 1 the total number of teacher goal interventions was identified as 197. The total number of learner goal interventions was 198. These totals can be used in one approach to calculating the likelihood (i.e. frequency) of a goal occurring in the script discussed below.

In the script shown in Figure 5.5, in the left column we have the teacher intervention, the central column represents a number of possible learner responses, and the right-hand column shows the teacher's counter response. In Figure 5.5, a box is a goal or sub-goal with associated likelihood of that goal occurring in a dialogue. For example, for the sub-goal 'target M or Ref', (Table 5.2 score = 29), the likelihood of this teacher sub-goal occurring in a dialogue = (29 x 100) / 197 = 14.7% . Circles are communicative acts. The arrows show the likelihood of the sequence of goals, linked by the arrow, happening. The *arrows going out* of a node in Figure 5.5 do *not represent all of the possible agent responses* (i.e. the exit arrows from a node do not add up to 100%), but instead represent a selection of often used 'intervention-response' combinations. The full data for intervention-response scores can be found in Section 3 of Appendix 5. Bold arrows in Figure 5.5 show weightings that are =>50%.

The sequences shown in the mentoring script have percentage weightings (on the arrows shown in Figure 5.5), which are derived from analyses 2 and 3 (an example of this approach to calculating often occurring sequences is given below). We can cross check the mentoring script in Figure 5.5 against the mentoring stage 3 state transition network (Figure 5.4), which involved the initial use of 'target M or Ref' by the teacher.

It should be noted that 'assertion confirmation' (in the script) was often associated with the goal 'motivation encouragement' (used in the network). In the network in Figure 5.4, we can see the sequence identified in the mentoring script (Figure 5.5). For example, in Figure 5.4 we have the following two routes through the network that are 'predicted' in the script.

Route one is: 8 to 9(TA: target M or Ref); 9 to 10(LA: monitoring evaluate); 10 to 9(TA: motivation encouragement); 9 to 10(LA: monitoring diagnose); END or 10 to 12(TA: motivation encouragement); END.

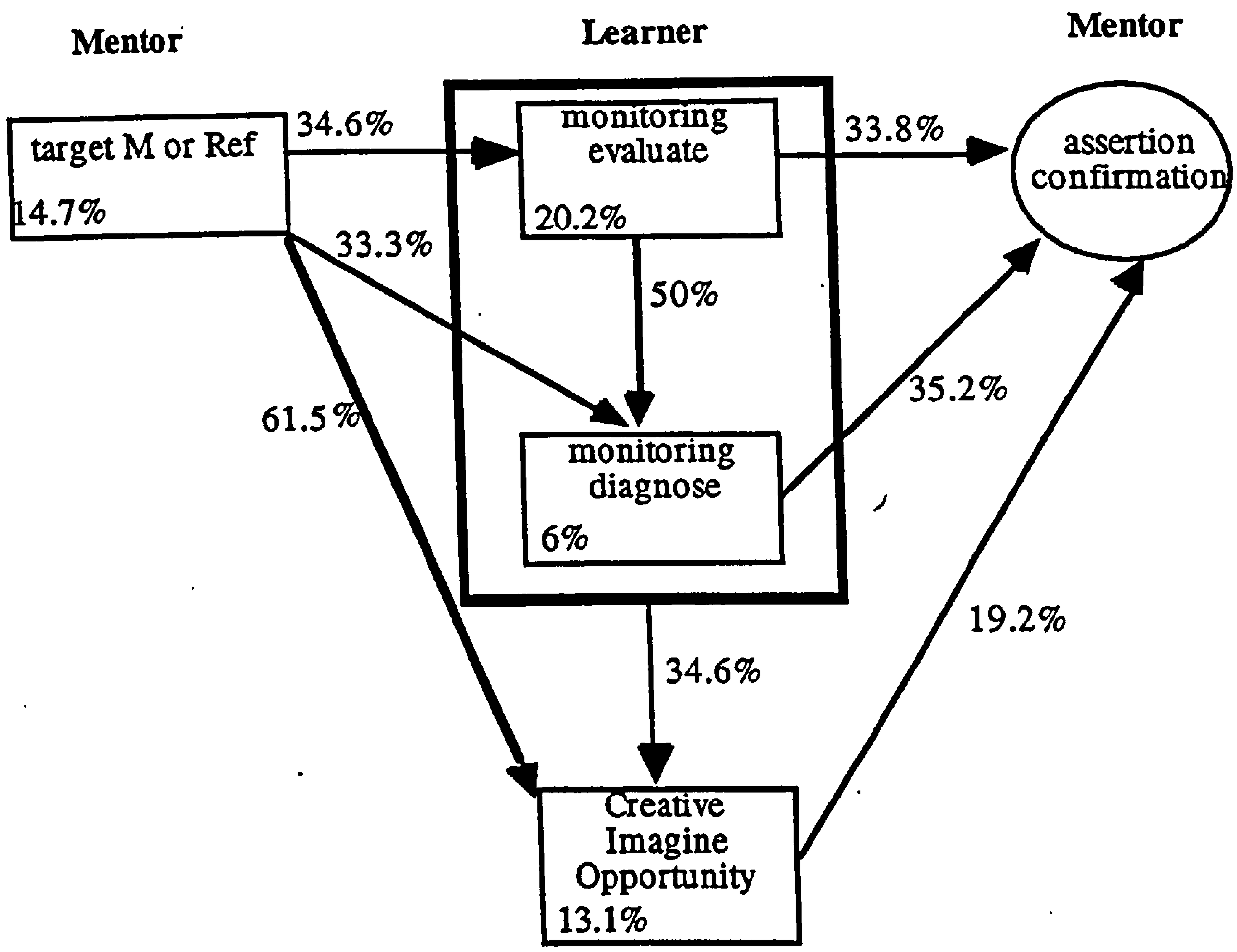

Figure 5.5. Mentoring script

Route two is as follows: 6 to 9(TA: target M or Ref); 9 to 10(LA: monitoring evaluate); 10 to 11(LA: monitoring diagnose); 11 to 10(LA: Creative Imagine opportunity); END or 10 to 12(TA: motivation encouragement); END. These routes were also in evidence the Stage 5 network (which is shown in Appendix 8, Section 2.5).

The above example, of how aspects of the script were derived, is only meant to be illustrative. One approach used to generating weightings on sequences (arrows) in the script is to use the spreadsheet, generated by analysis 3, of intervention-response counts (the spreadsheet is available in the Section 3 of Appendix 5). For example, the link shown in Figure 5.5, from learner 'monitoring evaluate' to mentor 'assertion confirmation' was derived from this analysis 3 spreadsheet. The spreadsheet showed that the most common mentor response to a learner 'monitor evaluate' was 'assertion confirmation' (spreadsheet cell score = 20). Therefore, the likelihood of this link occurring = (20 x 100) / 59 = 33.8%. Where 59 is the total number of different mentor responses to the learner intervention 'monitoring evaluate' (i.e. the total of the appropriate column on the spreadsheet). This descriptive model of decision making (although it is also semi-prescriptive) is discussed in the next section and has been used in the implementation of a prototype teaching agent.

The most 'typical' mentoring script was: TA 'target M or Ref' followed by LA 'creative imagine opportunity' followed by TA 'assertion confirmation'. The second most 'typical' script would be: TA 'target M or Ref' followed by LA 'monitoring evaluate' followed by LA 'monitoring diagnose' followed by TA 'assertion confirmation'.

5.4.6 Conclusion on results

If the main findings relating to the pause taxonomy and reciprocal modelling are taken together with the mentoring networks and mentoring script, then it is claimed that the analyses presented above have provided a detailed answer to our research question that is related to the empirical study (given in Section 5.2.2), although only for one small and specific instance of teaching.

5.5 Discussion

One result of our empirical study was the set of State Transition Networks (STNs) for the seven mentoring stages. In our approach the arcs represent sub-goals, which may lead to action or communicative acts. The nodes represent a state at which a decision is made about which transition should be selected next. These STNs can be used to structure interactions and to embed those interactions in computer systems (Winograd, 1987-1988). The networks could be used in a teaching agent to provide means-ends beliefs about which goals satisfy a particular mentoring stage. Often, more than one exit was possible from a state node. One way of structuring interactions would be to offer these options to a learner as a menu (the options would vary from one node to the next). Preferred options can be highlighted and some mentoring and negotiation (Baker, 1994) could take place if a learner did not accept one of these options. Thus, the STNs derived form our own empirical study could be used to give learners options for choice and would give the teaching agent expectations of answers and a principled position from which to mentor (principled in that the STNs represent a descriptive model of what one teacher actually did with four students).

Teaching agents like Blandford's WOMBAT (Blandford, 1991; Blandford, 1994) tend to draw upon the agent designer's intuitions in order to assign preference weightings in mechanisms that make decisions about what teaching intervention to make. In WOMBAT, for any goal that can be satisfied by more than one sub-goal or action, there is a list of possible sub-goals or actions. For each possible sub-goal or action there is a list of means-ends beliefs about what 'values' (an affective attitude held by the agent, e.g. promote monitoring) that action satisfies, plus there are related functions that compute under what conditions a value is relevant (i.e. when a relevance function will return true). There is a separate list of all the values with a numerical weight attached to each value to reflect its relative importance to the system. In Blandford's system all preference weightings are set by the designer of the agent. However, by drawing on the study described in this chapter, an agent would be provided with empirically based measures of the degree (a preference weighting) to which a sub-goal or action satisfies a value. Data indicating the most popular combinations of learner intervention and teacher response (analysis two and three) would provide an empirically based resource for assigning preference weights to a teaching agent interactive response mechanisms. Empirically based measures of the degree (i.e. preference weighting) to which a sub-goal or action satisfies an agent's goals can be calculated (the mentoring script shown in Figure 5.5 illustrates this approach). Thus, for example, if a learner asks a question, the mentor could have a preference weighting, to making an assertion response, of 6.6 (out of 10), which is a medium-strong preference. This is easily calculated using: (intervention-response score x 10) + total score for intervention.

The systematic interpretation of the data described in this chapter went further than proving the adequacy of the theoretical framework; it generated several new results which, we propose, would be useful in the design of a teaching agent. It is in this sense the framework can be said to be systematic (i.e. there is a strong link between theory and data).

5.6 Summary of empirical work

Mentoring takes place principally by a combination of goals used by the teacher that aim to promote learner creative, metacognitive and critical thinking. Students and teacher naturally play different roles in such a dialogue: the teacher carried out more 'critical probing' goals whereas the students engaged in more monitoring and reflection. An important part of this process was shown to be reciprocal modelling, i.e. students modelling the teacher as well as the teacher modelling learners. Pauses have been shown to be indicators, in context, of reflection. Descriptive models of seven mentoring stages were generated (STNs) and a prescriptive script of mentoring interactions was also presented. In summary, the main findings described in this chapter were as follows.

- The mentoring approach taken and the support given by Coleridge appears to have **encouraged some learner creativity.**
- Some internalised, learner **self-monitoring took place.**
- The two most **frequently used teaching interventions** related to critical thinking were 'critical probing' and 'critical judgement'.
- **Some goals belong exclusively to certain agents** (e.g. 'critical probing' was only used by the teacher) and others belong almost exclusively to one agent (e.g. 'critical clarification' and monitoring and reflecting were used by the learning agent).
- The teacher was making **many musical actions.**

- Although the total goal scores for teacher and learner were roughly the same, the categories of goals used by teacher and learner were often different.
- The **means** used by the teacher to **promote 'creative imagine opportunity'** were (mostly) 'target M or Ref' (target monitoring or reflection).
- Students seem to **perform monitoring before** they **imagine a creative opportunity**. Some heuristics emerged from analysis two. 'Critical probing' was the teacher's most often used interactive goal. 'Critical probing' was not only used as an intervention for eliciting an accurate prediction from one learner, it was also used if the learner was not responding with monitoring and creative like utterances.
- **This research identified four categories of pauses** (a turn was allocated to one of these on the basis of the interaction context). Suggestive evidence was found of a link between pause length and learner ability.
- The study identified the occurrence of **reciprocal modelling** (where participants in learning interactions build up models of the other participants' expectations).
- There was evidence for **seven mentoring stages**.
- **State transition networks** were generated for all seven stages of mentoring that represent a descriptive model of the four observed sessions.
- The most **'typical' mentoring script** was: TA 'target M or Ref' followed by LA 'creative imagine opportunity' followed by TA 'assertion confirmation'. The second most 'typical' script was: TA 'target M or Ref' followed by LA 'monitoring evaluate' followed by LA 'monitoring diagnose' followed by TA 'assertion confirmation'.

Chapter 6 - Computational Model and Implementation of a Mentor

6.1 Introduction

The KMf described in Chapter 3 was designed to guide the analysis and modelling of human teacher-learner interactions in problem-seeking domains. The empirical study described in Chapter 5 investigated in detail the mechanisms of interactive learning in the specific domain of musical composition. The study presented evidence that a mentoring style of teaching can promote higher-order, metacognitive thinking in learners. This chapter presents the last two components of our design approach: computational model and computational implementation.

In our theoretical model (Section 3.3), an agent is understood to be an integrated natural or AI system where, in "order to satisfy their values, agents derive goals from them and then form intentions to take action to reach these goals" (Kiss, Domingue et al., 1991). To recap, creative reflection in this thesis is an overall pedagogical value and is defined as the ability of a learner to imagine opportunities in novel situations and to then make (verbally) accurate predictions about these opportunities. In our theoretical model the teaching agent valuing (an affective attitude) creative reflection means that the agent 'likes' to encourage the learner to 'verbalise their compositional plans and intentions and to monitor and reflect on the outcomes of action'. Thus, a value is attached to possible situations of promoting learner creative reflection. The agent may then decide to form a further attitude of wanting the possible situation of creative reflection, this want will lead the agent into adopting pedagogical goals, because it already has the attitude of valuing them because these goals can promote creative reflection (i.e. the goals represent states of the world which an agent explicitly desires to achieve). Values in our theoretical model can be seen as being persistent, they cannot be dropped easily like goals.

In other terms, because our theoretical model proposes that the teaching agent values creative reflection, it will try to ensure that the interactions with the learning agent have certain properties; specifically, the interactions will intend to support learner creative reflection by providing vision through creative thinking, by making metacognitive interventions, by providing challenge through critical thinking, and by fostering motivation to learn (i.e. by mentoring interactions).

Reciprocal modelling and the *pause taxonomy* (two of the four main findings presented in Chapter 5) *are not implemented in the agent presented in this thesis* (this is post-doctoral work; however, some implications of these findings for AI-ED are discussed in detail in Section 7.2.2). Instead, the prototype agent described below (our computational implementation) is focused on issues raised by the implementation of a state transition network and the mentoring script[28]. Therefore, only components of the agent are implemented in what will be termed a pre-prototype (although a full computational model for our agent is presented).

A pre-prototype is limited in what it can do because it only incorporates some but not all features of a full system. The reason for taking this approach is that one important claim that is argued for in this thesis is, that an iterative approach to user-centred design of teaching agents (in problem-seeking domains) has been developed that is based on a principled and systematic relationship between theoretical framework [TF], analysis techniques [AT], computational model [CM] and computational implementation [CI]. Consequently, as we have already articulated our theoretical framework in Chapter 3, and have detailed how our analysis techniques generated empirical results in Chapter 5, what now remains is for us to provide the last two systematic link in our argument; namely, a teaching agent design [CM] that computationally instantiates [CI] aspects of our theory (the goal tree categories) and empirical work (the STNs and data related to the mentoring script).

The design [CM] and implementation [CI] of our teaching agent is described in, respectively, Sections 6.2 and 6.3. In Section 6.4 details are presented of the

[28]A preliminary design for the empirically based teaching agent was first presented in Cook (1997b), at the AI-ED 97 'Workshop on Pedagogical Agents' (Kobé, Japan), in a paper called "An Empirically Based Teaching Agent for Supporting Musical Composition Learning".

correlation between the implemented teaching agent and the empirically derived STNs. In Section 6.5 we present a formative evaluation of the teaching agent. Finally, in Section 6.6 we provide a summary of this chapter.

6.2 Computational Model: design of teaching agent

Following Kiss, Domingue, et al. (1991) in our theoretical model a teaching agent is characterised in terms of:

what it perceives,

what it knows,

what kind of reasoning it can do,

what values and goals it has,

what actions it can take

and some related agent-theoretic concepts.

The above characteristics of the theoretical model of our teaching agent were instantiated in the computational model of the teaching agent (i.e. our agent design) as follows.

The *sensory inputs* to the teaching agent come from: (i) input by the student into the teaching agent in the form of a list of numbers to transform a four note musical pattern, and (ii) an interface that structures the learner's interactions by presenting menu options, buttons and data input boxes (these are used to present a restricted number of goals and acts and to thus enable interaction). These inputs are subject to a variable degree of *perceptual processing,* e.g. the learner input list is analysed to see if there is evidence of large interval jumps (which may form musical phrase boundaries). Perceptual processing results in the teaching agent building a representation of environmental knowledge (in the example given, it also represents an attempt to infer the learner's musical intention with respect to their phrase). An Interaction History is also built up by a perceptual processor. An Interaction History is a summary of goals and sub-goals used with a learner and a summary of both types of sensory input. The mentor has a simple User Model reasoner (a perceptual processor). A User Model is an abstraction over the Interaction History *(it does not include mechanisms for belief maintenance).* The simple User Model is used to make decisions about interactions and forms the basis for the Learner Profile, which is output after a session with the teaching agent. A Learner Profile thus includes a log of the student's answers to questions and their reflections. The Learner Profile is intended to be used by a student as the basis for more self-reflection, or for further discussion with a teacher or with another student.

What the teaching agent 'knows' is very limited (this is a pre-prototype) and is open to questioning by the learner[29]. The focus for the teaching agent is on the potential that the choice of intervals provides for music to be sectionalised into phrases. Heuristics on how this is taught have been taken from the interaction data and augmented by some musical grouping constraints as proposed by Lerdahl and Jackendoff (Lerdahl and Jackendoff, 1983; Lerdahl, 1988). These cognitive constraints are specified in more detailed in Section 6.2.2.1.

The teaching agent is capable of certain types of symbolic reasoning based on its knowledge. For example, the teaching agent 'knows' that 'an interval leap of 23 or more may indicate a phrase boundary'. The agent also knows some good teaching tactics (intermediate level sub-goals); for example, a tactic for critical probing is that of getting the learner to imagine that they are playing their phrase on an instrument, as this can help the learner firm up their own perception of the purpose of the interval leap (in metacognitive terms 'go-above' and regulate their knowledge). This gives a good example of the challenge of mentoring in a problem-seeking domain, i.e. mentoring involves tutoring with non-absolute rules, where there is no right or wrong answer. Normally, if the perceptual processor detects a large leap then critical probing would be selected as an appropriate intervention. Some of the state transition networks (empirical results, see Section 5.4.4 and Appendix 8) are marked with

[29]This aspect of 'knowledge negotiation', Moyse, 1991, has not been implemented in the current version of MetaMuse.

heavily used transitions in bold. These routes were given a high preference when deciding on which aspect to implement in the prototype agent. Often, more than one exit was possible from a state node. Interactions are structured by offering all of these choices to a learner as menu options (these options would vary from one node to the next). Preferred options would, it was decided, sometimes be indicated to the learner if there was a strong basis (empirically based) for the teaching agent making a suggestion to the learner. Thus, the STNs are used to give options for choice and provide expectations of answers. A measure of confidence in the degree of learner co-operation could then be built up over time, based on the degree to which a learner fails to match the teaching agent's expectations (e.g. how often do they ignore advice given by the teaching agent).

The *values* and *goals* of the teaching agent can be either long-term fixed objectives called the value system or short-term temporary goals. The teaching agent action cycle shown in Figure 3.3 (see Section 3.3) is used to co-ordinate agent activity. Preferences for certain intermediate goals to meet values are taken from analysis 6, which was described in Chapter 5 (and are thus, as we have mentioned above, based on the STNs). Sub-goals are more dynamically compiled during interaction because they include details of **appropriateness conditions** and **preference weightings** to decide on what intervention to make (this approach was discussed in the context of Blandford's agent in Section 2.4; our approach adapts Blandford's). *Communicative acts* in the teaching agent can take the form primary acts (i.e. assertion, question, request, offer, accept and reject) or they may be musical actions (e.g. playing a phrase) for the learner to comment on. The form that an act takes is governed by a move function for particular circumstances (only one example of this design feature was actually implemented, this will be described in Section 6.3.4).

In the teaching agent action cycle shown in Figure 3.3 (see Section 3.3) various questions need to be addressed: Where do we start in the cycle? How does an interaction participant decide what to say in a given context? In order to participate in a mentoring interaction, the agent must be able to generate utterances which it believes can satisfy its values. Thus, the design of the teaching agent consists in "defining the computation that lead from sensory inputs to knowledge; and lead from values/goals and knowledge to action." (Kiss, Domingue et al., 1991, p. 3)

The following *interaction analysis implications* and *design assumptions* have been adopted in our teaching agent design:

1. Making predictions about how a phrase or piece will sound is a key ability for a composer.

2. There are seven mentoring stages involved in a full mentoring interaction sequence:
(i) Open session with extrinsic motivation.
(ii) Introduce task and initial probing with goal of making sure that the task is understood.
(iii) Initial use of Target M or Ref with goal of promoting monitoring and 'creative imagine opportunity'.
(iv) Mentor led critical thinking using probing and judgement with goal of giving direction on how to give predictions and imagined opportunities.
(v) Target M or Ref used (iterate 3-4 times) with goal of leaving space for the learner to give predictions and imagined opportunities.
(vi) Return to Mentor probing with aim of getting 'accurate prediction' (if not already achieved) or more 'creative imagine opportunity'.
(vii) End session.

3. State transition networks for all seven mentoring stages (which are all shown in Appendix 8) can be used to constrain goal selection and therefore limit the amount of reasoning that is required at a particular point in the mentoring interactions. The third and fourth stages of mentoring were selected to explore the implementation problems involved in adapting the state transition networks, the mentoring script (or more generally the data on which the script is based), and the heuristics below, to

agent theory and the agent architecture. Implementing the remaining mentoring stages and other analyses findings will be carried out as post-doctoral work.

4. 'Target M or Ref' (the asking of open-ended questions, e.g. "Was that what you intended?") will be the default intermediate goal for promoting 'creative imagine opportunity'. This intermediate goal ('target M or Ref') forms the basis for stage 3. Note that the teaching agent's approach to preferences is illustrated by the mentoring script given in Section 5.4.5, but that this approach is extended in the teaching agent (usually on the basis of more empirical data) and is formalised in the preference mechanism as weightings for values and likelihood of a sequence of goals and/or acts occurring. Some heuristics and preferences related to 'target M or Ref' emerged from the interaction analyses:

(i) The teaching agent will anticipate that the student will follow its 'target M or Ref' intervention with 'monitoring' and then 'creative imagine opportunity'. If the mentor is unable to detect evidence of monitoring, for example, then repair strategies ('critical probing') will be implemented to see what went wrong and attempt to achieve monitoring by the student.

(ii) The mentor will offer the advice that learners should, when asked a question, use the strategies 'evaluate' then 'diagnose'.

5. 'Critical probing' is another of the mentor's intermediate goal response:

(i) As stated above, 'critical probing' will be used if the learner is not responding with monitoring and creative like utterances (i.e. as a repair strategy).

(ii) When the user model indicates that a learner has achieved 'competence' at 'creative imagine opportunity' (measured as a result of systems requests for the student to make a self-assessment about their ability to come up with interesting ideas[30]) then 'critical probing' will be used as an advanced strategy by the mentor to achieve accurate predictions by the learner. For example, in music a probing question would be 'where would you put the phrase boundaries in the piece you have

[30]Note that this aspect of the design was not implemented in the current version of MetaMuse.

just written'?

6. Motivation encouragement is a key goal, it will be used frequently to keep a session running smoothly.

A question that required addressing in this thesis was: what should be the relationship between what one student does with the mentor (in the corpus) and what gets mimicked in the teaching agent? The above list of interaction analysis findings translated into design assumptions can be taken as one possible answer to this question. The six design assumptions have been taken as the scope of the prototype teaching agent.

The design of the teaching agent is modular, after Kiss, Domingue et al. (1991), as shown in Figure 6.1. According to Kiss, Domingue et al. (1991), each module could be regarded as being an agent in its own right. The overall architecture could therefore be a multi-agent one[31]. The design of each module is now described in turn below.

[31] However, in the current implementation each module relies on the other to constitute a complete agent.

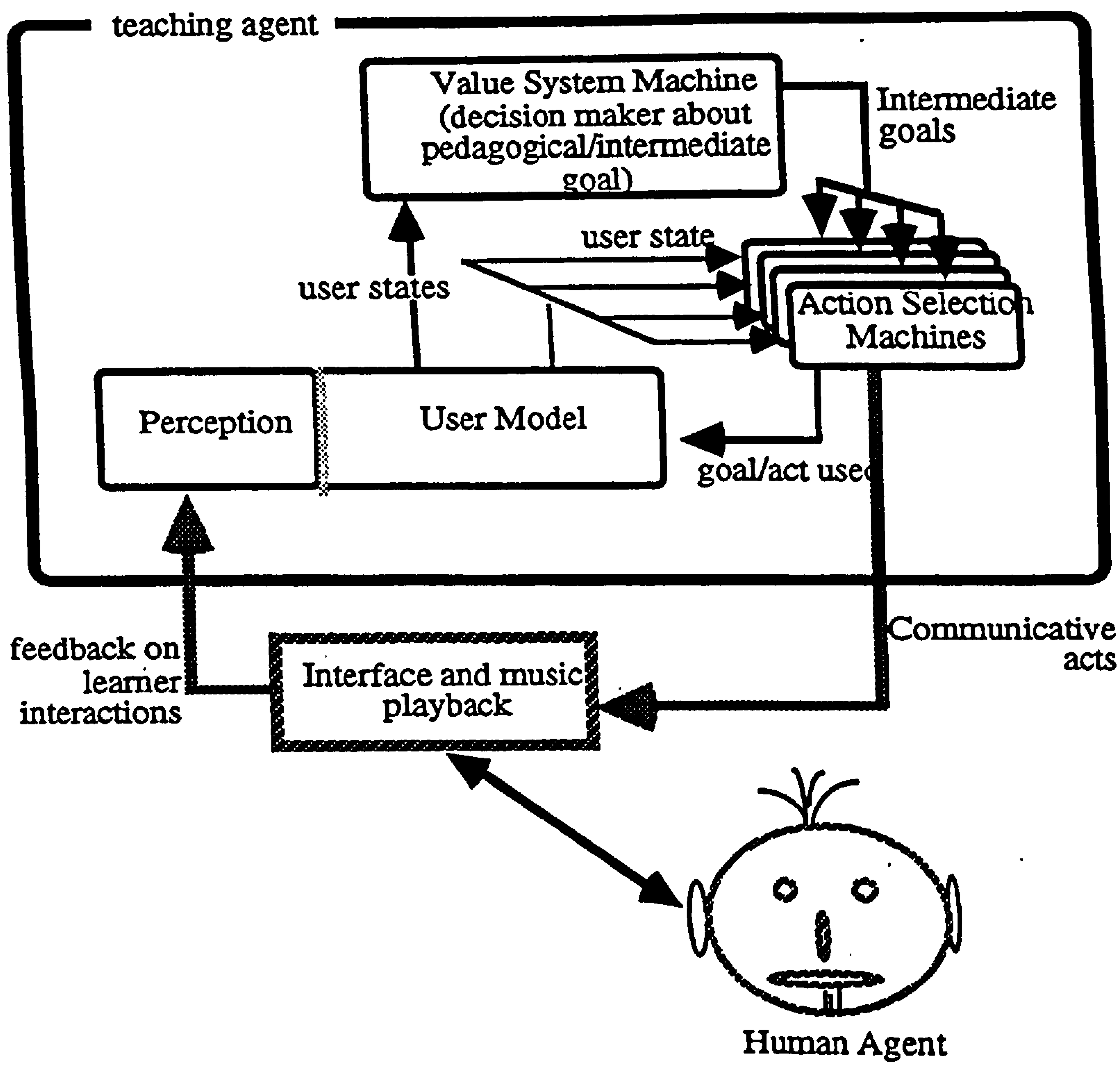

Figure 6.1. Teaching agent overall architecture.

6.2.1 The Value System Machine

The overall objective is to construct a teaching agent which attempts to support the learner's attempts at creative reflection with respect to a task (reflecting on the inner structure of a musical pattern). This objective arises because, as we stated above, in our theoretical model the teaching agent values creative reflection. Various goals will be added to the agent's list of wants to achieve this overall value.

Measuring a learner's ability at creative reflection is problematic, because the problem space is an open-ended one, where there is no correct solution. It is, however, possible to keep track of learner attempts at monitoring. Therefore, the computer agent will not attempt to assess 'creative imagine opportunity', it will rely on learner self-assessments[32]. Performance by the student will, however, be

[32] This aspect was not implemented in the current version of the agent, but could be in future work.

measured against some of the interaction analysis based design assumptions stated above (e.g. the mentor will expect learner monitor-evaluate to be followed by monitor-diagnose). Essentially, the mentor will have expectations about the sequence of sub-goals pursued by a learner. Deviation from a sequence will lead to negotiation and mentoring, plus an evolving, if simple, User Model (UM).

The teaching agent action cycle shown in the middle of Figure 6.2 takes an input from a network of preferred goal sequences (i.e. an empirically derived state transition network). The network taken will depend on the mentoring stage reached (only the network for mentoring stage 3 and 4 were implemented in the prototype). Representing a mentoring stage within the agent is a direct representation of the agent's values. The mentoring stage networks represent preferred plans. However, as mentoring starts (at run-time) any inputs from the User Model (which includes an abstraction of the Interaction History or IH) will be used to adapt the plan. This run-time plan adaptation will result in the selection of a series of pedagogical goals for execution. This adaptation makes use of various appropriateness conditions and preference weightings (some of which are empirically derived, the next section provides further discussion of this point).

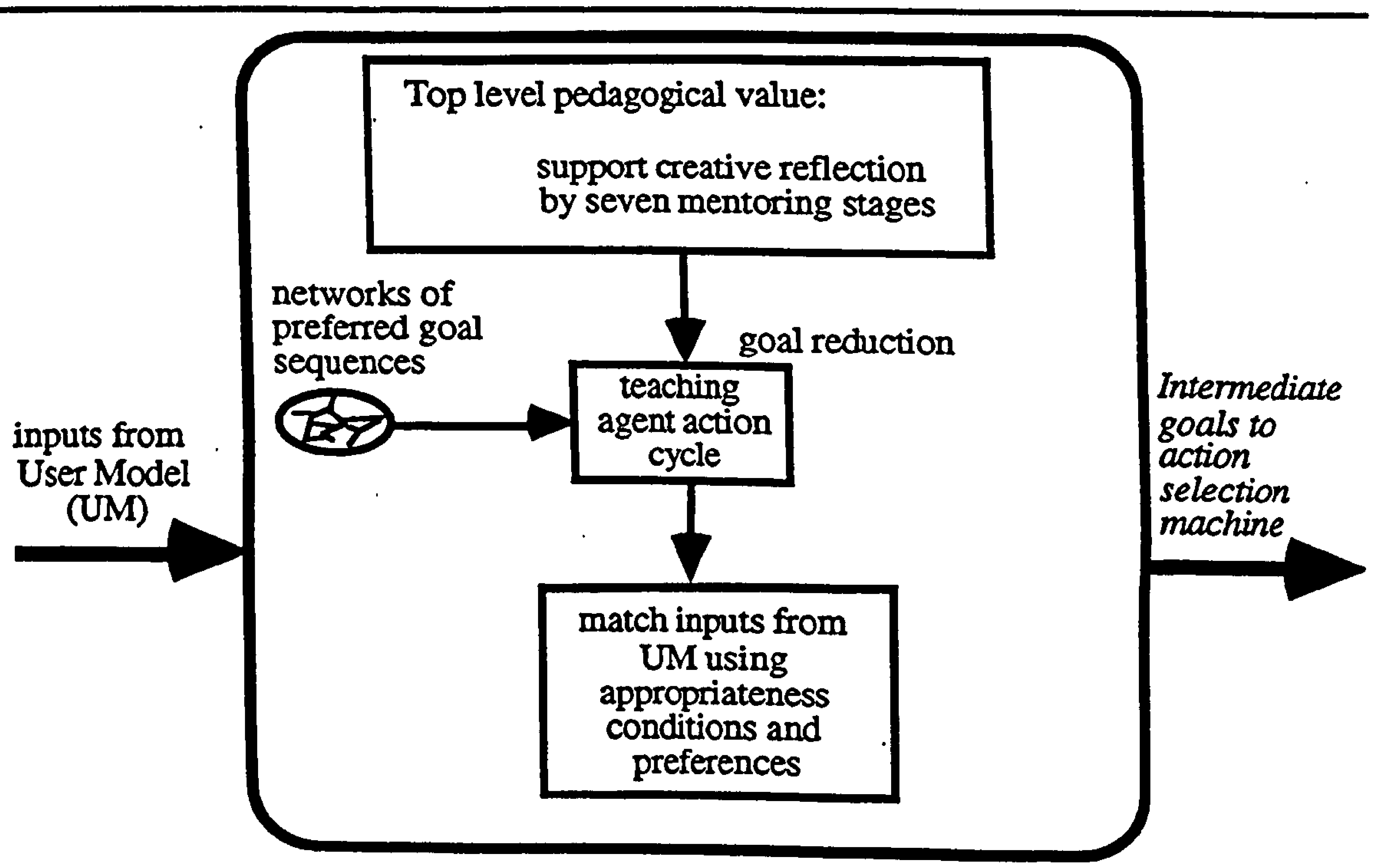

Figure 6.2. The Value System Machine (goal directed decision maker).

1. Creative reflection is valued, and the state transition networks for the seven stages are the preferred way of expressing this value (consequently the networks are 'hard-wired' in the agent's interface manipulation code, which Resides in the Value System Machine):

if it is the learner's turn they are only presented (in a Respond menu) with the learner exit nodes that exist for the current node
or
if it is the teaching agent's turn, make use of agent routines to select an appropriate list of intermediate sub-goal (i.e. to generate wants)
then do steps 2 to 7.

2. Select intermediate sub-goal from list of wants (by preference weightings and/or appropriateness conditions) that goes furthest in satisfying current pedagogical goal(s) (as specified by the current node of the STN).

4. Form an intention to a communicative act to meet an intermediate sub-goal.

5. Consult User Model, adapt communicative act template if required (as specified by the move function), commit to communicative act, perform act and 'notify Perception' that it is done.

6. If the communicative act is one which caused a 'parent' sub-goal to be reached then consider the 'parent' sub-goal satisfied.

7. If all goals for a mentoring stage are satisfied, consider the stage completed and move onto the next mentoring stage.

Figure 6.3. Pseudocode for the action cycle.

Like Blandford's action cycle (1991, pp. 126), an agent's activity involves many iterations of the action cycle while traversing a 'goal-action tree'. In descriptive terms, the stages of the action cycle (Figure 3.3, Section 3.3) are as shown in Figure 6.3 in 'pseudocode'.

6.2.1.1 The goal-action tree

Following Blandford (1991), the form of representation used to indicate the relationships between goals and actions is a tree structure, with the teaching agent action cycle being viewed as a tree traversal mechanism. In this architecture the form of representation which is used to indicate the relationships between goals and actions is an and-or tree structure with the condition that: a set sequence is imposed on the 'ands' as specified by the appropriate network diagram, only one goal is relevant at a time; 'ors' are not mutually exclusive (the agent will have a preferred branch, but may decide to traverse a different branch in certain circumstances). For intermediate goals there may be a combination of goal reaching communicative act or actions.

In an interaction between two agents, any agent will be traversing their own goal-action tree. The mentor will be attempting to get the learner to adopt certain mentoring goals (thus the goal trees will overlap). The tree representing the way in which the mentor intends to achieve learner acceptance of these goals will look different to how the learner will intend to achieve these goals. The partial goal trees for each agent in Figures 3.1 and 3.2 in Chapter 3 illustrate this point very well. In this thesis the mentor starts with a liking for a particular goal tree (based in part on the current node reached in the network), changes are negotiated with the learner (this negotiation aspect was not implemented).

6.2.1.2 The decision mechanism

For any goal that can be satisfied by more than one sub-goal or action there is a preference weighting, which is empirically derived from common routes in the network diagrams or intervention-response analysis (Section 6.3.4 explains this point in more detail). Each sub-goal or communicative act will have associated with it means-ends beliefs about what values that action satisfies, and how well (as measured by empirically derived numerical strengths) and under what conditions (these are called 'appropriateness conditions' for turn sub-goals and 'move functions' for utterances). Thus, each value has a numerical weight attached to reflect its relative importance to the system. Apart from the empirical source of weights of preferences, this approach is very similar to Blandford's (1991).

6.2.2 The Perception Machine

The *sensory inputs* to the teaching agent come from: (i) lists input by the student into the interface in the form of numbers to transform a four note musical pattern, and (ii) menu or button selections by the student on an interface that structures the interaction and related free text input, (iii) inputs from the Value System Machine. These inputs are subject to a variable degree of *perceptual processing*, which results in the teaching agent building a representation of environmental knowledge as follows:

- The learner input list is analysed by a 'Grouping Constraint Reasoner' (which is explained below in Section 6.2.2.1) to see if there is, for example, evidence of large interval jumps (which may form musical phrase boundaries).
- An Interaction History is also built up by a perceptual processor. An Interaction History is a summary of goals and sub-goals used with a learner and a summary of both types of sensory input.
- The teaching agent has a simple User Model reasoner. A User Model is an abstraction over the Interaction History, together with knowledge about previously elicited states of the agent and aspects of the domain. Elicited states take the form of a response by the learner to the structured questioning by the teaching agent (this aspect, i.e. previously elicited states, was not implemented in the pre-prototype teaching agent).

The perception machine is shown in Figure 6.4.

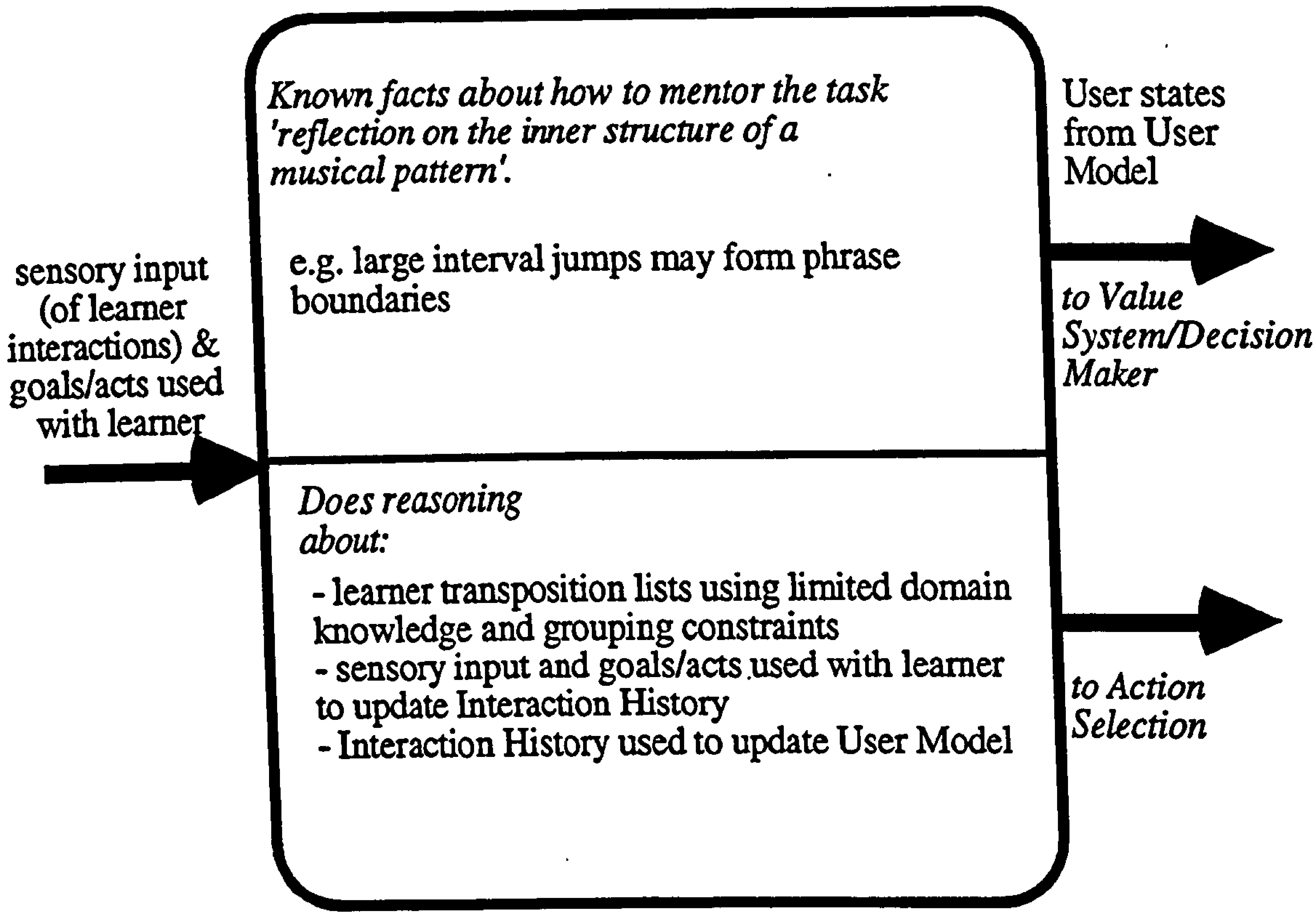

Figure 6.4. The Perception Machine (not goal directed).

6.2.2.1 Grouping Constraint Reasoner

The learner input list is analysed by a 'Grouping Constraint Reasoner' to see if there are any recognisable patterns in the list that could form the basis for mentoring interventions. This reasoner takes as its starting point part of Lerdahl and Jackendoff's (1983) generative theory. In one aspect of their theory, they describe a set of rules that assign structural descriptions to hierarchical aspects of musical structure (but which neglects motivic processes). Their theory claims that listeners unconsciously infer hierarchical structure from musical surface, one of these being 'grouping structure', or the segmentation of the musical flow into units such as motives, phrases and sections. Lerdahl (1988) has proposed, in the context of most listeners understanding of certain pieces of serial music, that if a composer wishes to close the gap "between compositional system and cognized result" that certain "psychologically plausible constraints on compositional grammars" should be taken into account. These are thus cognitive constraints for composers and listeners[33], two of which are listed below (using Lerdahl's, 1988, p. 240-244, own wording) with an associated rationale for its inclusion (again using Lerdahl's own wording), plus a relevant example from the interaction analysis described in Chapter 5:

Constraint 1: The establishment of local grouping boundaries requires the presence of salient distinctive transitions at the musical surface.
Rationale for 1: Segmentation into groups is accomplished at local levels largely by detection of *distinctive transitions* in the musical flow. A distinctive transition is a change in some musical dimension, e.g. a greater distance in attack points or a shift in register. From this it follows that constant change will not give rise to salient distinctive transition, nor of course will no change at all. Another factor creating local groups is repetition.
Example: Evidence to support the 'distinctive transitions' constraint was found in the interaction analysis described in Chapter 5:

> Now perhaps, see if you can be more, see if you can create a piece say for three or four sections in it, and use the interval distance to dictate the different sections. Let me give you an example, you might have one section which was, say, rises up in semi-tones, and the next section might be octave leaps or, do you think you could do?

Constraint 2: Intervals between elements of a collection arranged along a scale should fall within a certain range of magnitude.
Rationale for 2: Elements of a collection (e.g. pitch collections) can be placed along a dimension to form a scale. The intervals of a scale have general size limitations: they must be large enough for adjacent elements to be easily discernible, but not so large as to use excessive space along the continuum.

[33] In the pre-prototype teaching agent these constraints will limit the domain model that is implemented to the following aspects of composing a phrase: octave leaps, descending trajectory, ascending trajectory, large leaps, repeated transposition, and a small phrase.

Example: Evidence to support the 'range of magnitude' constraint was found in the interaction analysis. The teaching agent knew, for example, that "an interval leap of 23 or more may indicate a phrase boundary".

6.2.3 The Action Selection Machines

The Action Selection Machine, shown in Figure 6.5, receives intermediate sub-goals from the Value System Machine and attempts to satisfy these sub-goals by mapping input received from perception (about a user state, i.e. the User Model) into an action template, going out to the learner (via the agent interface) as a communicative act and to the Perception Machine (for the Interaction History).

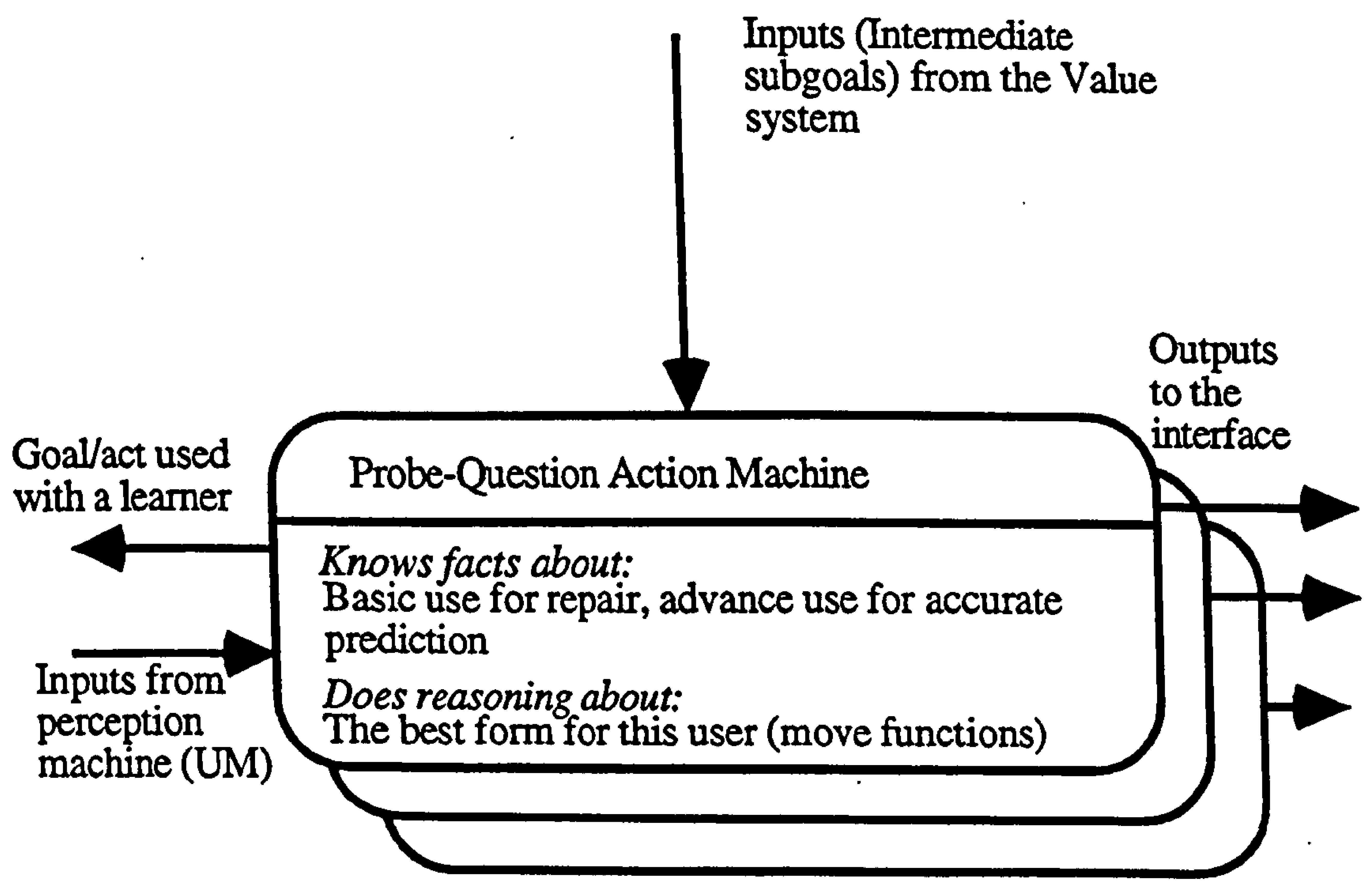

Figure 6.5. The Action Selection Machines (goal directed).

The input from the Perception Machine is used here to form an intention about which communicative act to become 'committed' to. This is because, although an initial plan was built by the Value System Machine, intervening sub-goals may have had an important affect on the User Model. Hence a localised adaptation is attempted in the Action Selection Machine (this is what the KMf regards as a move function: a communicative act made in a particular context). The Action Machines will know various facts. In particular, they will know that some metacognitive goal questions have an implicit intention to target a particular level of an agent. This knowledge makes an explicit link between a goal and intention adopted to take action to achieve that goal.

6.3 Computational implementation: MetaMuse

MetaMuse is, as we have pointed out above, a pre-prototype teaching agent that is based on the Knowledge Mentoring framework (Chapter 3), empirical data (i.e. the analysis of how a human teaches described in Chapter 5) and our wider computational model (described above). A pre-prototype is limited in what it can do because it only incorporates one or two features of a full system. What MetaMuse can do is structure the interactions with a learner in a way that will, hopefully, promote reflection. MetaMuse can only deal with a small task revolving around the chromatic transposition of a four note phrase (i.e. the same as for Coleridge, which was described in Section 5.2.1). A session with MetaMuse results in a Learner Profile, which is intended to promote further dialogue between learner and teacher.

MetaMuse can not understand natural language. The system is not able to engage in dialogue about the 'free text' inputs by the learner. As a result the system sometimes lets the user input some thoughts on what they are doing, stores these explanations and reflections in the Interaction History (this is then abstracted into the User Model), and then moves on to the next part of the session. Interactions with MetaMuse thus typically take the form of structured questioning by the system. However, within certain limitations, the system is able to comment on a musical phrase input by the learner.

The implementation was carried out by coding the teaching agent in Macintosh Common Lisp (MCL) version 2.0.1 on a Quadra 660av - this is the version of MCL that Symbolic Composer (Morgan and Tolonen, 1995) for the Quadra uses. Code can be loaded under Symbolic Composer (which handles Midi files and contains routines required for transposition of musical patterns). Thus, MetaMuse runs under Symbolic Composer. The basic approach to implementation was to take KMf and some of the empirical findings and merge them with:

- the agent design concepts of Kiss (described in this chapter and in Section 2.4);
- the agent implementation of Blandford's, that has been adapted for the purposes of this thesis (Blandford made the code for WOMBAT available for use in this research project in November 1997, WOMBAT was described in Section 2.4,); and
- Lerdahl's cognitive constraints for composers and listeners (two of which were described above in Section 6.2.2.1).

6.3.1 Pre-prototype interface design

The initial interface for the teaching agent is show in Figure 6.6 ('MetaMuse MainScreen'). The two palettes down the right-hand side of Figure 6.6 are part of Symbolic Composer. The 'Listener' window at the bottom of Figure 6.6 is Symbolic Composer's interface with MCL. The MetaMuse interface structures the interactions between the teaching agent and the learner by providing a series of menu options and buttons which are required to support both mentoring stage 3 (i.e. 'Initial use of target M or Ref' with objective of promoting learner monitoring and 'creative imagine opportunity') and stage 4 ('Mentor led critical thinking' using critical probing and judgement, with objective of giving the learner direction on how to give predictions and imagine opportunities).

The MetaMuse MainScreen, shown in Figure 6.6, reflects the task structure typically present in mentoring stage 2 ('explain task and initial probing') and the initial part of mentoring stage 3. When a learner clicks on a button, further text windows or dialogue boxes for input are displayed. Thus, the MetaMuse MainScreen enables MetaMuse to 'know' what task stage the learner is attempting. The static text window at the top of Figure 6.6 explains the task. Button 1 asks the learner to enter the transposition list, and when selected a dialogue box appears asking the learner to enter a list and to 'Return it'. A text information window is also displayed at this point, explaining that the learner is being constrained to considering the musical techniques of repetition, contrast and trajectory. This decision was taken in an attempt to give the prototype MetaMuse a chance of being able to reason about the musical intention of the learner. This approach also has its roots in the work of Lerdahl (1988), described above in Section 6.2.2.1.

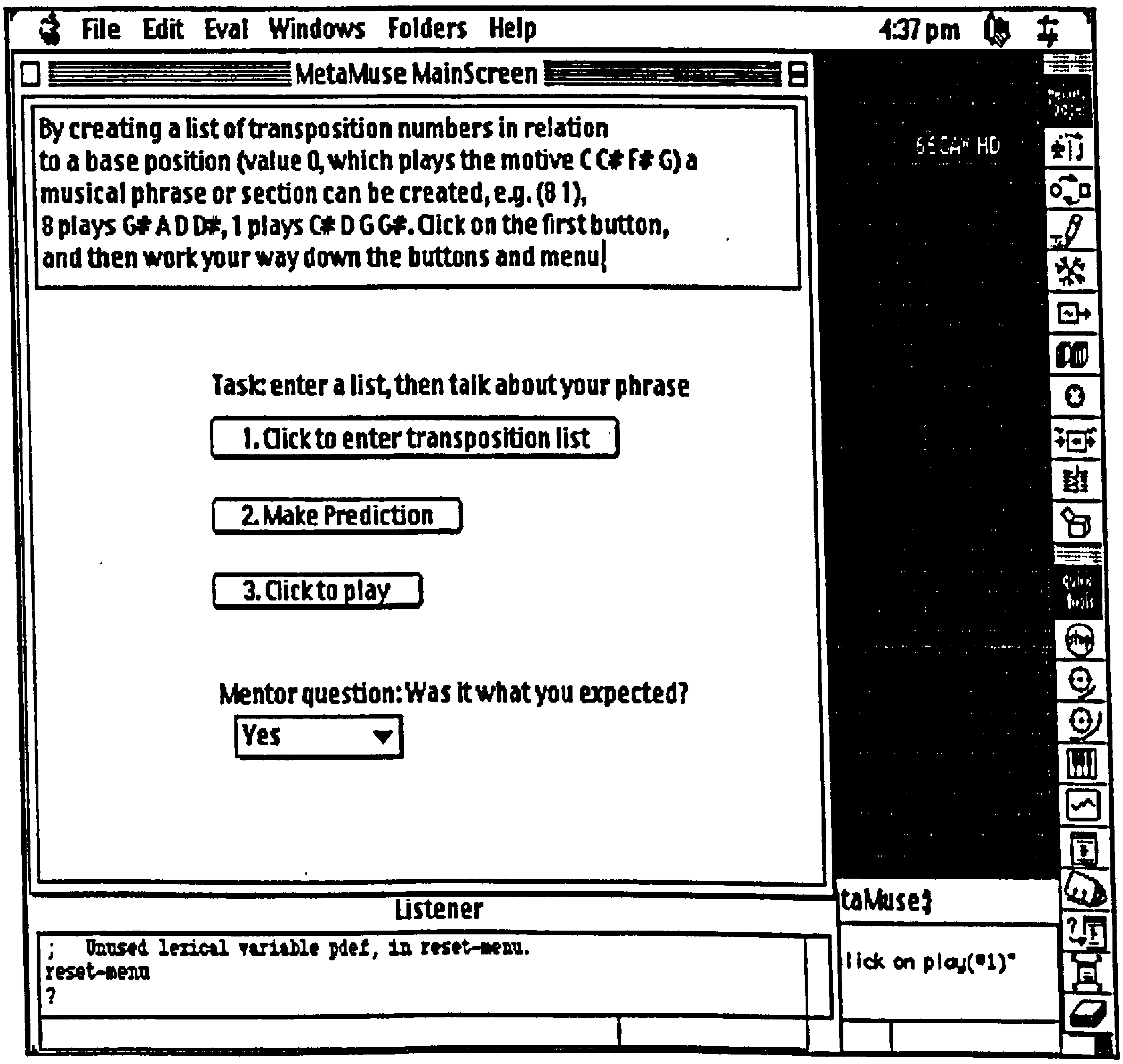

Figure 6.6. Interface for the teaching agent MetaMuse.

The text contained in the information window (explaining repetition, contrast and trajectory) provided by MetaMuse is reproduced below:

What are repetition, contrast and trajectory?

Local groups - Segmentation of a phrase into groups (e.g. motives) is accomplished at local levels largely by creating contrast in the musical flow.

Contrast - This where a distinctive transition occurs between two motives. Contrast allows the listener to hear a change from one musical grouping to the next. Elements of a collection (e.g. a pitch collection) can be placed along a dimension to form a scale. However, the intervals of a scale have general size limitations: they must be large enough for adjacent elements in a local grouping to be easily discernible, but not so large as to use excessive space along the continuum. For example, an interval leap of 23 or more semi-tones (which can be said to use excessive space) may indicate a phrase boundary, i.e. a contrast between one motive and the next.

Repetition - A factor creating local groups or sections is repetition.

Trajectory - Transposition of a motif sequentially (i.e. small interval values) can produces a phrase with a 'direction'. It is something happening in time - as well as in direction (up down and coming back on itself).

The dialogue box containing the transposition list (input by the learner) does not remain on the screen when the user clicks on 'Return it' (learners are being encouraged to memorise the changes they make to a phrase).

The learner must then click on button 2 (on Figure 6.6) and the system will then prompt the learner to verbally predict (to themselves or to another student) how the phrase will sound when it is played back. In this sense MetaMuse has been designed for learners to work (and learn) in pairs. This is a design decision taken on the basis of our intuitions (i.e. it not based on empirical data from our empirical study). The learner is also prompted to enter and return a text version of their prediction.

By using the option '3. Click to play' button on Figure 6.6, the learner can hear what the phrase sounds like when the transposition list they have just entered is applied to the basic motive (this works in exactly the same way as Coleridge, see Section 5.2.1). Should the learner have failed to enter a list using option 1 or a prediction using option 2, they will at this point be asked to do so (again, this is a design decision taken on the basis of our intuitions). In the current implementation, following a click on button 3 (and assuming steps 1 and 2 were completed) the midi-file player palette shown in Figure 6.7 is generated (with the title 'Click to play').

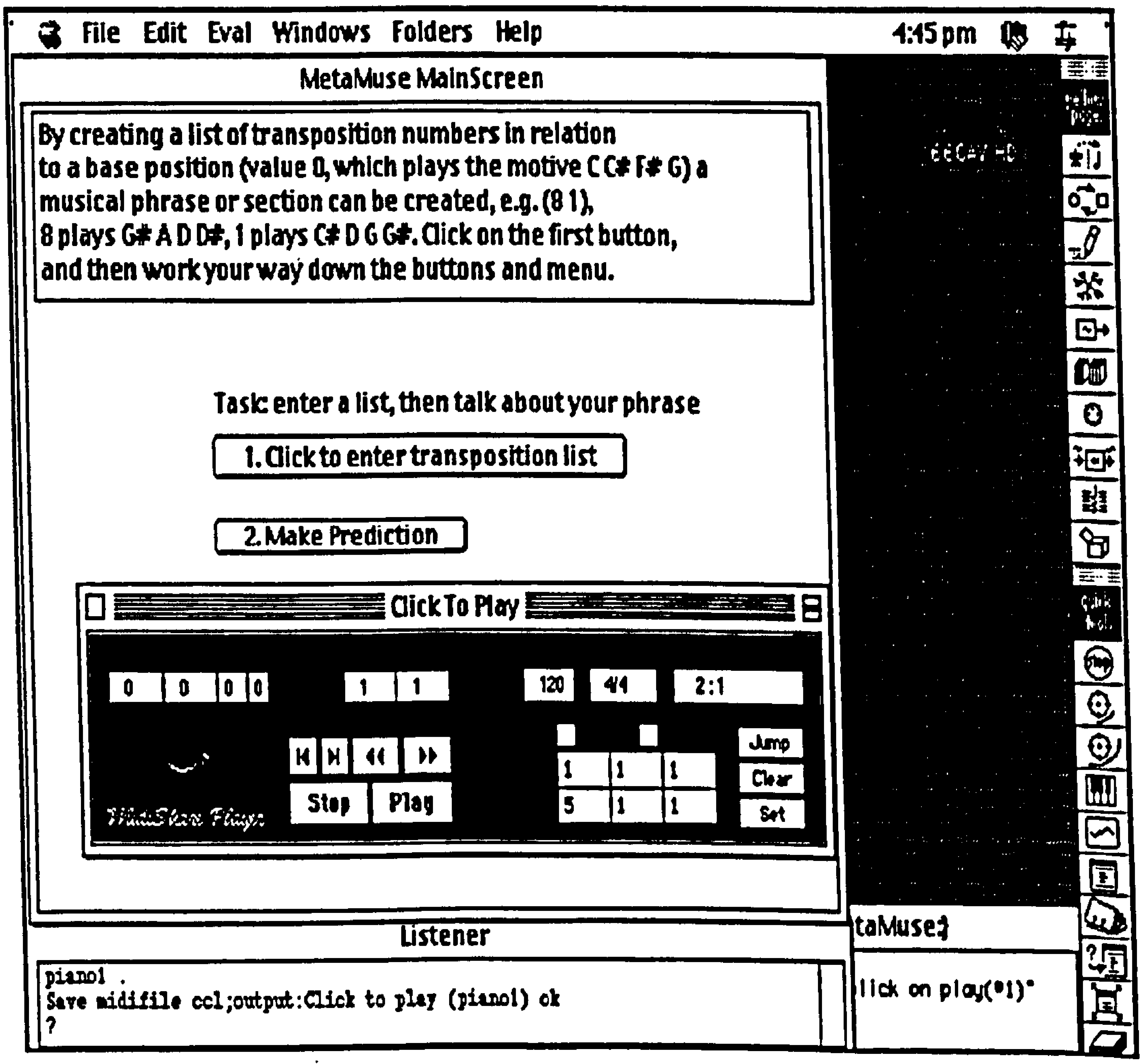

Figure 6.7. Midi-file player palette.

The pop-up menu at the bottom of the MetaMuse MainScreen (unnumbered option 4 in Figure 6.6, with the Mentor question above it "Was it what you expected?") is really the start of mentoring stage 3 and can lead to a number of mentoring options, which are specified by the State Transition Network for that stage (see Figure 5.4 in Section 5.4.4). When the learner selects (the unnumbered) option 4 they are presented with a pop-up menu allowing answers of 'yes' or 'no' or 'maybe'. At this point a real implementation problem arose: what are the options to respond to a button click or menu selection? These options can be summarised as follows:

1. Natural language understanding.
2. Functional description language used by learner.
3. Some selections could go to a range of button choices; however, others may lead to free text box, what to do then?

The first option is, in the view of this researcher, a long way from being a reality and is not the focus of this research (such an approach would be a research project in itself). The second option is cumbersome for a learner. If this project had available to it 12 programmers, then a teaching agent could have been implemented like that of Lester and his team (Lester, Converse et al., 1997), reviewed in Section 2.4. Unlike Lester, Converse et al., this project did not have such resources available. The implementation was therefore a restricted one. MetaMuse is a teaching agent that knows a lot at the interaction level, but not the domain level (it is tutoring with incomplete knowledge). MetaMuse attempts to engage in interaction based on design option 3, i.e. it presents a set of structured menus and interfaces with buttons. It allows some free text to be entered but at the moment does not analyse that free text (this could be post-doctoral work).

An alternative to the above three options would be to say that the teaching agent is not stand-alone and that it is to be used as an assistant by a human teacher. The teaching agent would structure the learner's responses around its interface and generate reports for a human mentor to read. The teaching agent implemented for this project does in fact take this approach: when a learner exits the system a 'Learner Profile'[34] is produced as an aid to further dialogue between human teacher and the learner. This decision was taken so that the project could be seen to produce an educationally useful tool (i.e. a computer-based tool or teacher's assistant that provides a solution to the musical education problems that are described in Section 2.1). Such an approach is consistent with the user-centred design approach (described in Chapter 4) that is being used to guide the approach to teaching agent development being taken in this thesis. This design decision also gives a clear example of the choices that have to be made when moving from interaction analysis findings to teaching agent implementation. In this work we argue that it is not simply a question of direct transference of the corpus to a system, rather, it is one of incorporating some functionalities from the corpus, and then, extending them to what an artificial teaching agent can do in addition. In this case, MetaMuse extends what the human agent did by providing a profile of the structured interactions that have recently taken place with the system.

In the current implementation of MetaMuse, if the learner selects 'No' (or any option) from the pop-up menu at the bottom of Figure 6.6, the teaching agent 'wakes up'. This is indicated in Figure 6.8 by three new options in the menu bar (i.e. 'MetaMuse_Help', 'Exit' and 'Respond') and the appearance of MetaMuse's output window, which contains communicative acts from the teaching agent (which in Figure 6.8 is summarising what has just happened and giving a recommendation to the learner). The decision to add to the existing Symbolic Composer menu (rather than put up a new menubar) was taken because of the inability to compile a new phrase in Symbolic Composer if a new menubar was used. (Note, that the Help menu at the far right of the menu bar in Figure 6.8 appears automatically and is related to Mac OS 8, the operating system used on the Quadra.)

[34]An example of a Learner Profile is given in Figure 6.12.

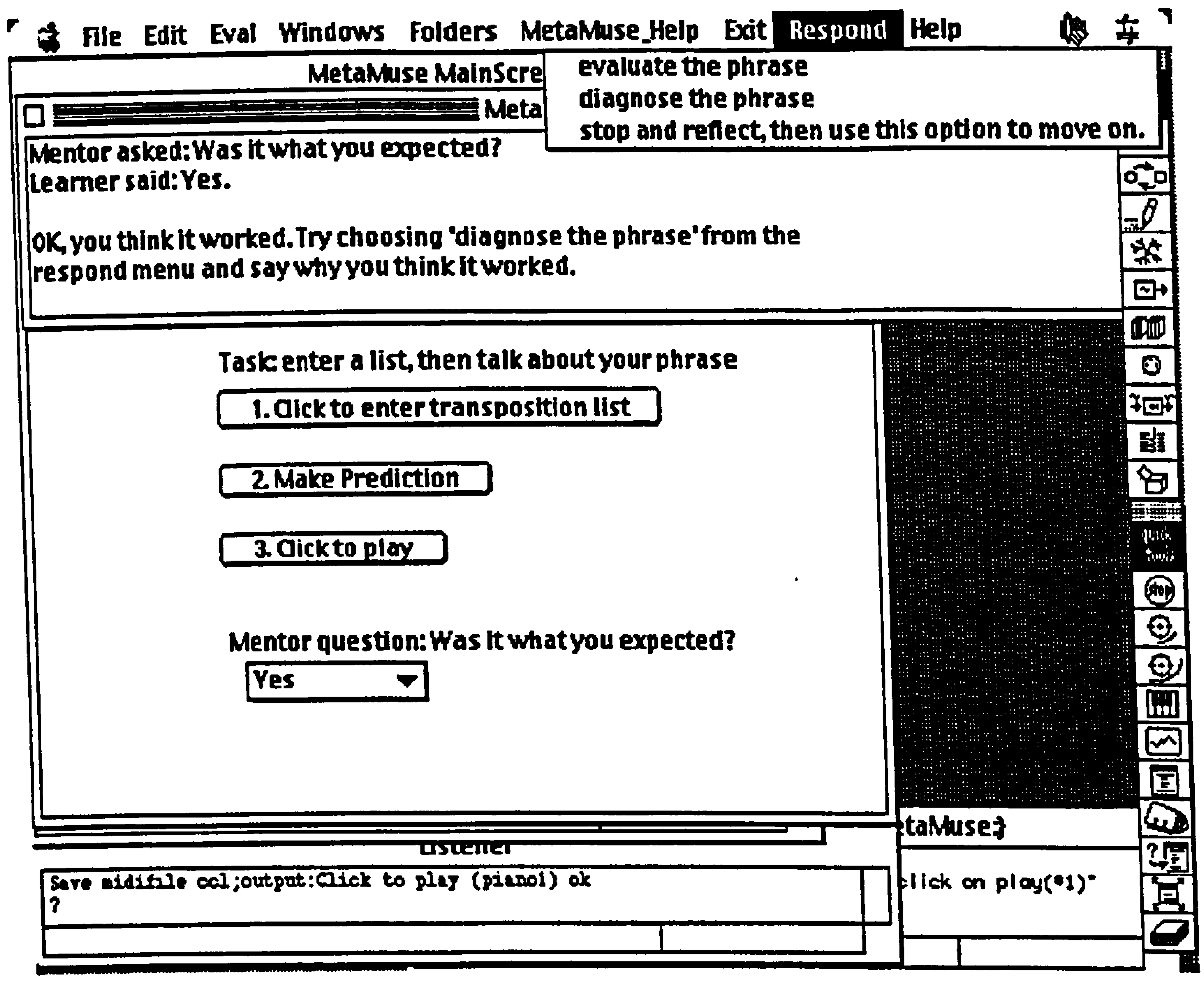

Figure 6.8. Teaching agent activated, Respond level 1.

In the current implementation of MetaMuse, the contents of the Respond pull-down menu, shown in Figure 6.8, are:

Respond, with sub-menus (for node 9, see Figure 5.2 in Section 5.4.4):

- Evaluate the phrase
- Diagnose the phrase
- Stop and reflect, then use this option to move on

Help, with sub-menus:

- How does transposition work in MetaMuse?
- What are repetition, contrast and trajectory?
- Why learn how to predict?

- What is mentoring and creative reflection?
- Display my transposition list

Exit

- End mentoring session

The Help menu exists as a catch-all that attempts to explain aspects of the task and mentoring. The Help menu also provides the option for the transposition list to be displayed (a dialogue window appears with the title 'Problem definition' and a listing of the transposition values input by the learner). The 'Exit' option takes the user back to the normal Symbolic Composer menu (shown in Figure 6.6). When this option is selected a 'Learner Profile' for the current session is automatically displayed.

The Respond menu is the main focus of responses by the learner. The construction of utterances by the learner (using menus, buttons and get-string dialogue boxes) is structured into three levels:

- Respond level 1 (menus).

  If it is the learner's turn, then depending on the current state node reached in a network, the Respond menu will display all exit transitions (as defined by the relevant STN) for the learner for that node. These represent intermediate level sub-goals in the KMf.

  When the learner selects an option from the Respond menu, they will be presented with additional buttons and dialogue boxes in order to enable them to make a communicative act (the bottom level of the KMf described in Chapter 3).
- Respond level 2 (buttons).

  If the turn can potentially be expressed by more than one communicative act (CA), e.g. assert and question, then the learner is presented with an 'Interaction Box', from which to select the CA that bests suits their purposes. The decision about what Respond level 2 CAs to offer for a particular sub-goal is based on the goal hierarchies shown in Figures 3.1 and 3.2 (Chapter 3), which are empirically based trees showing which acts were used to serve which sub-goal (the empirical source of these trees is explained in Section 1 of Appendix 4). When a learner selects an act from the Interaction Box, they will drop to Respond level 3 (see below). It is by the repeated selection of CAs from the Interaction Box that a learner can build up a turn that has a Move Function.

- Respond level 3 (get-string dialogue boxes).

  If a level 1 sub-goal only involves one CA type, e.g. only an 'assertion' is required for 'evaluate', then the learner is presented with a dialogue window and is prompted to input free-text relating to the current sub-goal. Respond level 3 inputs may also arise out of selections made at Respond level 2.

An example of Respond level 1 is shown in Figure 6.8. When the learner first activates MetaMuse by selecting the button to answer to the question: "Was it what you expected?", MetaMuse responds by putting up the three new menu options ('MetaMuse_Help', 'Exit' and 'Respond'). At this point MetaMuse also places in the Respond menu all the possible learner exits from node 9 of the state transition network for mentoring stage 3 (Figure 5.2 in Section 5.4.4). The three options are shown in the pull-down respond menu in Figure 6.8, and are 'evaluate the phrase', 'diagnose the phrase' and 'stop and reflect, then use this option to move on'.

An example of Respond level 2 is shown in Figure 6.9. The learner has selected the second Respond option (not shown) of 'Provide clarification in response to the question' (the question being referred to is shown in the MetaMuse output window in Figure 6.9) and has been presented with the Respond level 2 Interaction Box, from which the learner can either make an 'assertion' or ask a 'question'. Once the learner has built up a response they must select the 'Move on' button.

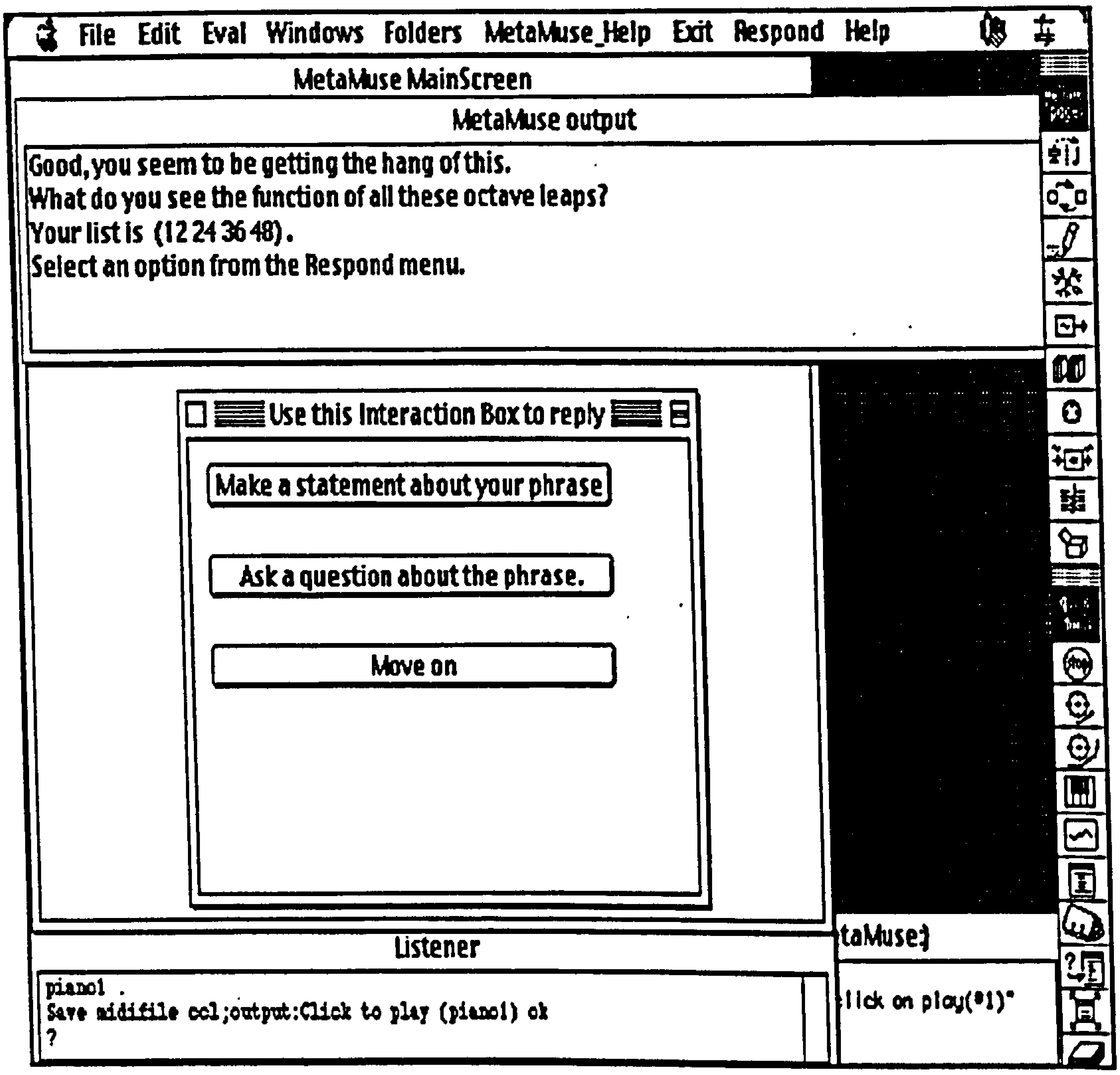

Figure 6.9. Respond level 2 for learner sub-goal 'critical clarification'.

An example of Respond level 3 is given in Figure 6.10. The learner has selected the top button from the Interaction Box (shown in Figure 6.9 and 6.10): 'Make a statement about your phrase', which leads MetaMuse into putting up a dialogue box for the learner to enter an 'assertion', which should provide clarification about what was intended (by the learner) by the octave leaps (the learner's list contains values that are all multiples of 12, and which are hence all octaves).

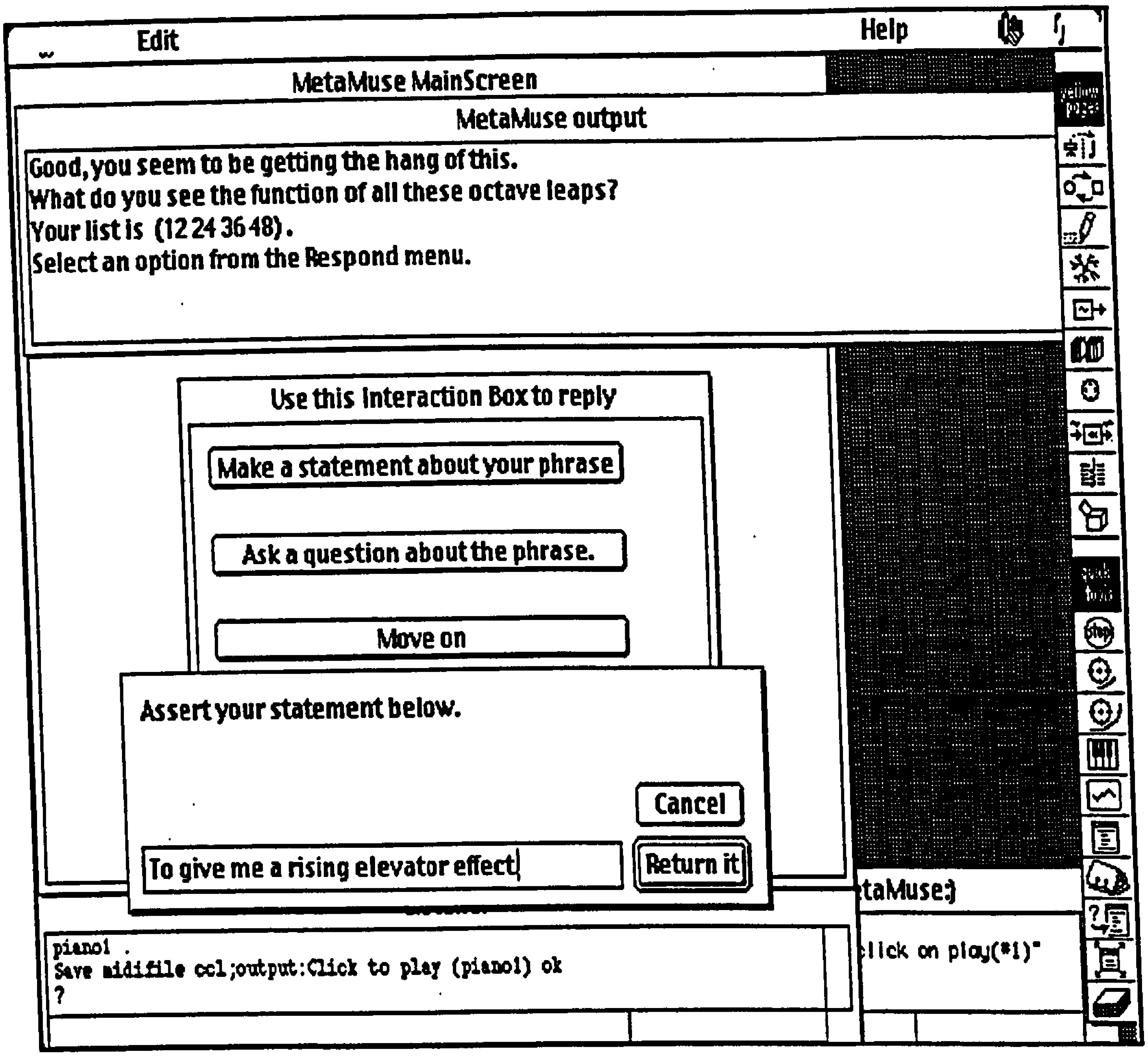

Figure 6.10. Example of respond level 3 for learner 'assertion'.

As will have become apparent from the above three examples, the three interface levels are designed to drop down the screen. So level 1 is at the top in the menu, level 2 sits in the middle of the screen, and level 3 is towards the bottom of the screen. Furthermore, it will have also become apparent that the names of menu options try to anglicise the KMf terminology as much as is possible in an attempt to make MetaMuse user friendly. Finally, Figures 6.9 and 6.10 provide an example of how MetaMuse makes use of its limited domain knowledge to probe the learner and check that they are composing in an intentional manner.

6.3.2 User modelling and learner profile

As was pointed out in Section 3.3, a fine-grained user model of user misconceptions is not maintained. MetaMuse does, however, use its interactions with a learner and construct various sub-lists, one of which is a list of beliefs about the learner's goal-hierarchy, i.e. they are beliefs entered by the user. This 'belief structure' is a list encoding information about what the teaching agent believes the user believes. There is an assumption of sincerity about the user's input:

> 'I (the learner state that I) believe X', therefore based on the assumption of sincerity, the teaching agent believes that the user believes X.

The belief structure is held in the User Model and is used at the end of a session with MetaMuse to help generate the Learner Profile, which contains beliefs and other lists on the following:

- The questions asked by MetaMuse and learner responses, (beliefs inputs by the learner) that relate to the following turn sub-goals:
  - Prediction about phrase
  - Evaluation (initial)
  - Evaluations made elsewhere in interactions
  - Diagnosis
  - Imagined opportunity
  - Paused to reflect on an opportunity on x occasion(s)
  - Critical thinking (clarifications)
- MetaMuse's analysis of learner's phrase.
- A listing of the learner's phrase.
- The number of times the learner has refused advice.

The above Learner Profile is output by MetaMuse following a session, and represents (TA believes (model of LA)). The implication of this approach (i.e. of generating the Learner Profile) is that the teaching agent is not being used as a stand alone teaching agent, instead it is (as we have pointed out above) seen as a tool that is to be integrated into the classroom in order to promote further learner dialogue (e.g. predictions and explanations) and reflective engagement. These types of dialogues can occur when the teacher discusses the Learner Profile with the student, or when students discuss their profiles with each other.

6.3.3 Planning in MetaMuse

As we saw above, in the current implementation of MetaMuse the learner is presented with a 'Respond' menu that structures interactions in the manner described in Section 6.3.1. As a learner responds at one node, MetaMuse takes them forward along one of a number of possible transitions to the next state node. The decision 'why' choose one path (transition) over another is taken, in MetaMuse, by agent routines that make use of a preference mechanism (which are described in the section below). Thus, although the STNs only provide a semi-open plan of how a learner could proceed, the learner is in fact free to refuse advice and follow one of the other routes defined by the STN for a particular mentoring stage. This can lead to unexpected learning that is not unwelcome. However, MetaMuse can be prescriptive. For example, MetaMuse keeps track of the number of times advice has been refused and may, in certain circumstances (if advice on a particular topic is ignored three times), limit the exit nodes available to the learner, thus prescribing the exit transitions from a particular node that the learner takes. The decision to be prescriptive was not based on empirical data, it represents a design decision taken on this thesis author's intuition. (In Section 7.2.2.2 we will compare our approach to planning with other AI-ED approaches to making use of STNs in planning.)

6.3.4 Decision making (preference mechanism)

Decision making in MetaMuse is, where possible, based on empirical data from the interaction analyses (Chapter 5). A diagram showing the architecture of the preference mechanism (in terms of its functional decomposition) is shown in Figure

6.11. For any node that can be satisfied by more than one sub-goal, there is a list of these possible sub-goals (these are wants and are represented in a goal tree called `dialogue_tree_get`, which is shown in Figure 6.11). For each possible sub-goal there is a list of means-ends beliefs about what values a sub-goal satisfies, and under what conditions, i.e. when the relevance function returns true (`me_get` in Figure 6.11).

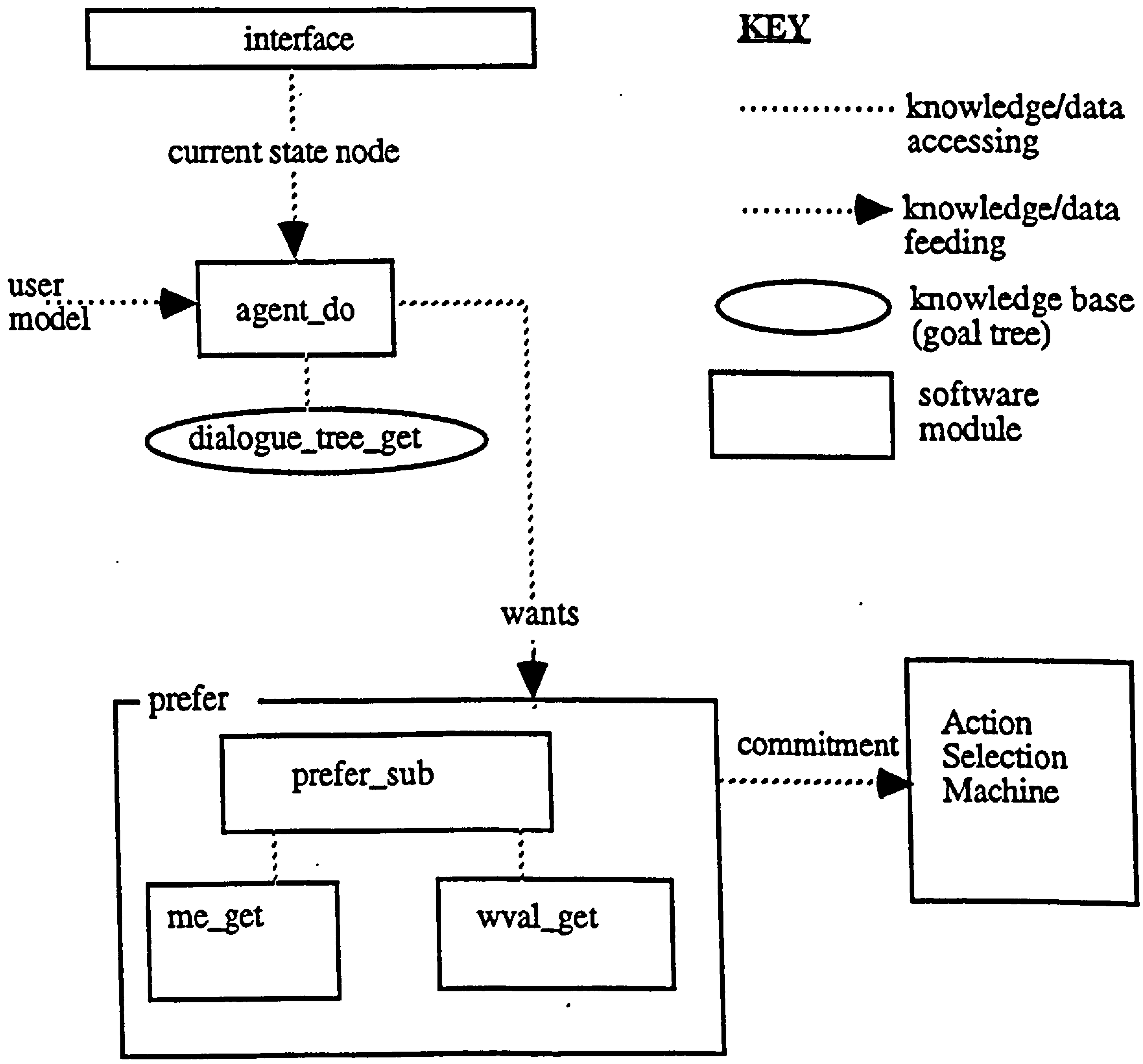

Figure 6.11. Architecture of the preference mechanism.

There is a separate list of all actions that achieve values, with a numerical weight attached to each value to reflect its relative importance to the system (`wval_get` in

Figure 6.11). Unlike Blandford's system, our agent provides empirically based measures of the strength by which a sub-goal or action satisfies a value. In Blandford's system all strengths are set on the basis of the designer's intuitions (i.e. Blandford's). To illustrate this approach to decision making we now describe the workings of `me_get`, one of the principle routines controlling the preference mechanism (the full code for which is given in Section 1.2 of Appendix 9).

`me_get` gets the means-ends beliefs relevant to the current decision. MetaMuse uses the details of the current state node in order to help it make a decision. For example, for `node_10` the mentor exit transitions are represented as the following Lisp functions (in MetaMuse's goal tree, which is in the structure `dialogue_tree_get` in the Value System Machine):

```
target_M_or_Ref_2
critical_probing_1
motivation_encouragement_1
critical_judgement_1
critical_probing_2
```

The above list of wants for node 10 is passed on to `me_get` by `agent_do` and each want (the turn sub-goals shown above) is evaluated in turn, the function with the highest weighting (weightings are contained in `wval_get`) AND whose relevance function returns true (as determined by `me_get`) is selected, and MetaMuse commits to that sub-goal. If we take, as an example, the sub-goal function called `target_M_or_Ref_2` (which actually resides in the Action Selection Machine), from the above list; it is represented in `me_get` as follows:

```
(target_M_or_Ref_2 (diagnose_follows_evaluate
(no_diagnosis ,*believes*)
```

`target_M_or_Ref_2` is only considered if it's associated relevance function no_diagnosis is evaluated as true. no_diagnosis is a function that returns true if there is no learner diagnosis in the list *believes*, i.e. the learner has not input a diagnosis, they may have selected a different respond menu option, etc. If no_diagnosis returns true, then the weighting for the associated value (i.e. for diagnose_follows_evaluate) is selected by wval_get (the weight of 50 from the mentoring script is used, this is calculated from empirical data, see method 2 below). Thus, if the function no_diagnosis evaluates to true then the weighting of 50 goes into the final reckoning (which is done by a function called findbest, which is not shown in Figure 6.11) of all weights returned for this node (node 10). As this example illustrates, a weight for the sub-goal target_M_or_Ref_2 only comes into play in the preference mechanism if the learner has not pursued a 'monitoring-diagnosis' sub-goal earlier in the interactions.

Section 1.2 of Appendix 9 gives an example of how preference weightings (which reside in wval_get) were arrived at from empirical data and then used in our version of the preference mechanism. To illustrate the approach we describe two methods to calculating weightings below (examples of how this is implemented are given in the Lisp function wval_get, which is in Section 1.2 of Appendix 9). Note that the preference mechanism is an extended version of the mentoring script described in Chapter 5, but put into the context of agent decision making. Also note that likelihood has been defined in this thesis as the chances of successful achievement of a goal.

Method 1 is as follows. Analysis 3 intervention-response counts (the spreadsheet in Section 3 of Appendix 5) are used to derive the likelihood of links occurring in the mentoring script (see Section 5.4.5). This approach is used to calculate script-like links in the preference mechanism. For example, taking monitoring evaluate to motivation encouragement (specifically assertion confirmation, which includes all motivation encouragement plus dialogue management scores). The analysis 3 spreadsheet shows that the most common mentor response to a learner monitor evaluate was assertion confirmation (score = 20). Therefore, the likelihood of this link occurring = (20*100) ÷ 59 = 33.8%. Where 59 is the total number of different mentor responses to the learner intervention monitoring evaluate (sum of column B in the spreadsheet shown in Section 3 of Appendix 5 of thesis).

Method 2 uses analysis 2 findings to generate the likelihood for a particular sequence. For example: for monitoring-evaluate to monitoring-diagnose (from analysis 2), it was found that 6 out of the 12 occurrences of 'monitoring diagnose' were preceded by 'monitoring evaluate' by the student. Therefore, the likelihood of this link occurring = $(6*100) \div 12 = 50\%$

Whilst the preference weightings method only gives a numerical weighting, it has been used with the STNs described above (which provide means-ends beliefs about which goals satisfy a particular mentoring stage). The preferences are used to deal with any conflict that may arise through multiple goals (i.e. how to select a sub-goal from a list of wants). In future implementations, the preference mechanism could be used when the need to negotiate new goals arises because a learner rejects the currently proposed mentoring plan (as defined by the STN).

Thus, MetaMuse uses the preference mechanism as its approach to making decisions about what exit transition a teaching agent should take from a STN node when it is its (the teaching agent's) turn. MetaMuse has implemented WOMBAT decision mechanisms but has extended them by both adapting them to the domain of music, and by using the data from our empirical study to both formulate preference weightings and (in some cases) to inform the relevance functions that specify the conditions under which a particular intervention should be selected. Given that WOMBAT was designed for tutoring in the domain of car design, and that we have adapted and extended it to meet the needs of our own domain, we conclude that the approach to empirically derived descriptive models of decision making appears to have the potential advantage of generality of applicability to other domains.

MetaMuse also provides one example of how a full prototype could implement the KMf concept of a 'move function' (see Chapter 3). The Action Selection Machine can specify what form or type of communicative act (CA) to use in a particular context. The function `CP_CA_decide` (shown in Section 2 of Appendix 9) demonstrates how adaptivity at the utterance level is provided by MetaMuse for 'critical probing' (CP). This approach represents a form of local planning at the communicative act level. `CP_CA_decide` reaches a decision about what act to perform for 'critical probing' on the basis of the contents of the global variable `*probing*` and `*analysis_type*`. The variable `*probing*` contains details of the last probing used (so that the Action Selection Machine knows what has happened before, if at all, i.e. which 'critical probing' type interactions were used with a learner, and can therefore avoid repeating itself). The types of probing recognised are:

```
leaps_segment,
playing_on_instrument,
how_many_phrases
```

These labels refer to the following possible types of 'critical probing' that are implemented in the current version of MetaMuse: does this large leap segment the music?, imagine you are playing the phrase on an instrument - how would you articulate it?, and where would you put the phrase marks in what you have composed so far? The variable `*analysis_type*` can contain either:

```
octave_leaps
decending_trajectory
ascending_trajectory
large_leap
repeated_transposition
boring
```

The above labels specify the conclusion that the Grouping Constraint Reasoner (in the Perception Machine) has reached about a learner's phrase, e.g. it uses octave leaps, it is a small phrase and is perhaps a bit boring, etc. (these labels and the associated concepts, are explained in Section 6.5.1).

6.3.5 Other aspects of pre-prototype teaching agent implementation

The operation of the action cycle (in the Value System Machine) is governed by a central controlling routine, `agent_do`. Its operation can be expressed as the pseudocode shown in Figure 6.12 (this is a modification of Blandford's `agent_do`):

---

if the learner has activated a new STN node by making a Respond menu selection,
then there is a relevant sub-goal outstanding, therefore establish wants for all sub-goals which might address the current node, commit to satisfy the preferred sub-goal;

(if appropriate) establish move function for the communicative act(s) which will satisfy the current sub-goal and commit to the preferred CA;

if committed to a basic communicative act
then tell Action Selection Machine to do it and make sure it tells you when it has done and tidy up when done;

if there are no sub-goals outstanding
then await learner response.

<u>Figure 6.12.</u> Pseudocode for `agent_do`.

Tidying up consists of updating the state of the teaching agent, noting the act which has been done (in the '`worldstate`', see `agent_state` below), checking whether the doing of the communicative act has resulted in any sub-goals being reached, and removing the act from the list of commitments. For intermediate sub-goals this involves checking whether all the sub-goals of a goal have been achieved for that learner (in the `worldstate`), and if so adding the goal to the list of done goals and removing the sub-goal from the tree of goals to be achieved.

The principal routines called by `agent_do`, which is in the Value System Machine, are as follows (these are adapted from WOMBAT code):

`agent_commit`

Calls the preference mechanism to select which sub-goal to commit to based on the current wants (and notes the commitment to the list of commitments).

`agent_goals`

Generates new sub-goals for the currently active state node by referring to the `dialogue_tree_get` (which defines the intermediate goal-action tree and which is itself derived from state transition networks) to establish what the sub-goals of the state node at top of the list of commitments are, and notes these goals in the list of goals. The code for `dialogue_tree_get` can be found in Section 1.1 of Appendix 9

`agent_wants`

Generates a list of all intermediate level sub-goals that are reasonable in the current context, by considering what node is currently active and by referring to the data in `dialogue_tree_get` to establish what sub-goals can make progress towards satisfying this space of possibilities (i.e. the current node). These possible sub-goals are listed as wants. Like WOMBAT, MetaMuse is currently constrained to satisfying one sub-goal at a time (multiple goals must be satisfied sequentially).

`agent_state`

This a cut-down version of the WOMBAT agent state. It is a representation of all the attitudes of which the agent is aware: wants, goals and individual commitments. All of these are encoded in the agent state (although binding in Lisp and the way we have implemented the STNs means that `*agent_state*` changes from node to node, which is what we intended).

```
(setf *agent_state* '((wants)
                      (goals)
                      (committed)
                      (worldstate (done) (goalreached
                       monitoring_evaluate)
                      (recent) system_turn user_exists)))
```

The above is used to set up the state of the agent, which is represented in a global variable called `*agent_state*`. The sub-lists for `*agent_state*` are:

`(wants)` - list of sub-goals that could be adopted for a given node. The agent 'wants' to do all of the possible sub-goals which are possible for the current node (if it is the teaching agent's turn). The teaching agent then forgets its wants once it is committed to one of the sub-goals.

`(goal)` - contains the system's beliefs about intermediate sub-goal to be adopted. These are obtained from the state transition networks.

`(committed)` - the actual sub-goal committed to out of the list of wants.

`(worldstate)` - a convenient list containing aspects of the state of the world: what the agent's done, what goals it's reached, whose turn it is, and whether or not a user exists. (This list doesn't really get used much in the current version of MetaMuse because features like turn are implemented as global variables.)

<u>Belief structure (`*believes*`)</u>

These are sub-lists of beliefs about the learner's goal-hierarchy, i.e. they are beliefs input by user and have been created for purposes of this research. The belief structure is a list encoding information about what the teaching agent believes the user believes. There is an assumption of sincerity about the user's input (which was discussed above in Section 6.3.2). The data structure below (a belief structure) actually gets re-initialised every time the learner selects an answer to the question: Was it what you expected?, on the initial MetaMuse interface (see Figure 6.6 in Section 6.3.1) and looks as follows:

```
(setf *believes* '((evaluation)
     (evaluation_initial)
     (evaluation_other)
     (diagnosis)
     (reflect_imag_opp 0)
     (reflect_predict 0)
     (imagined_opportunity)
     (prediction)
     (accurate_prediction)
     (clarification)
     (give_evidence)))
```

The sub-lists in the above belief structure are as follows:

`(evaluation)` - Contains the learner's first evaluation. This list stores the learner's monitoring in response to the question "Was it what you expected". The learner can select one of three responses: 'yes', 'no' or 'maybe'. MetaMuse 'knows' that if this list is not nil, that it will then contain one of the three previously stated monitoring evaluate responses.

`(evaluation_initial)` - Is needed because of way MetaMuse tests the variable `(evaluation)`. If the learner responds with anything other than, 'Yes' (i.e. 'The phrase was as expected'), then in a few turns time MetaMuse will work with learner to do 'critical probing'. MetaMuse needs to clear `(evaluation)` otherwise it keeps looping. Therefore, the learner's first evaluation eventually gets moved from (evaluation) to (evaluation_initial).

(evaluation_other) - Is needed because there are other opportunities for the learner to carry out monitoring after the initial attempt (this is particularly the case if the learner decides to take a path through the network that is not recommended by MetaMuse, i.e. the learner ignores MetaMuse's advice).

(diagnosis) - Contains the learner's diagnostic statement about why something did or did not work.

(reflect_imag_opp 0) - if a state node has as a learner exit transition of 'reflect imagine opportunity' then this is offered as an option in the Respond menu. If the learner selects this option they are encouraged to stop and reflect, and to then select 'Move on' when ready. reflect_imag_opp is initialised to 0 and incremented each time the user selects this option from Respond.

(reflect_predict 0) - if a state node has as a learner exit transition of 'reflect make prediction' then this is offered as an option in the Respond menu. If the learner selects this option they are encouraged to stop and reflect, and to then select 'Move on' when ready. reflect_predict is initialised to 0 and incremented each time the user selects this option from Respond.

(imagined_opportunity) - Contains the teaching agent's question, and the learner's assertions about some creative opportunity they have imagined.

(prediction) - Contains the learner's text version of the prediction they have made about how the phrase they have just created will sound when they play it back.

(accurate_prediction) - not used in the current implementation of MetaMuse.

`(clarification)` - This is heavily used in the current implementation of MetaMuse. Contains the teaching agent's question ('critical probing'), and the learner's assertion or counter question ('critical clarification'). This list can potentially contain 2-3 sets of teaching agent questions and learner responses.

`(give_evidence)` - not used in the current implementation of MetaMuse.

<u>Belief maintenance</u>

As was pointed out in Section 3.3., a fine-grained user model of user misconceptions is not maintained (i.e. standard beliefs held by an agent are not represented explicitly in the model). Beliefs in `*believes*`, once acquired, are never removed or altered. Beliefs about the domain (Grouping Constraint Reasoner) are fixed. There is clearly a lot of room for future versions of MetaMuse to work on its belief revision.

<u>Processing the user input</u>

Learner inputs are captured by menu options or clicks on a button. When a learner selects an option, if a proposition is involved, then the user's belief is recorded. If it is able to, the system then assesses the propositional content and establishes its own beliefs about the proposition. In the current implementation of MetaMuse this aspect is limited to analysing the learner's list and responding to the initial monitoring-evaluation.

6.4 Example interaction to illustrate how implementation links to STNs

Two sample analyses are given below in Tables 6.1 and 6.2 in order to illustrate the way in which the implemented prototype MetaMuse uses the State Transition Networks (STNs) to structure interactions with a learner. These extracts are taken from a "real" example generated by participant 5 in the formative evaluation of

MetaMuse (which is described in Section 6.5). These examples are provided because they can be seen as partially answering the research question posed in Section 1.1.3, i.e. the agent design research question.

In these examples an explicit link is made between how the STNs from our empirical work were used to structure interactions in the implemented teaching agent. All utterances by the teaching agent (TA) in Tables 6.1 and 6.2 appear as they are output by MetaMuse (i.e. the text has not been edited). Note that the STNs referred to below are given in Appendix 8. Also note that the version of MetaMuse used to generate the interactions shown in Tables 6.1 and 6.2 is the slightly improved version[35].

Prior to the example shown in Table 6.1, the 'learner'[36] had entered a transposition list of '0 8 16 12 -20 0 2 0 1 0 8 16' and returned it. Following a request by MetaMuse, the learner had made the following prediction about their phrase: "moving pattern up through octave and above, then returning to base only to begin again". Following playback of the phrase, the learner-MetaMuse interactions shown in Table 6.1 then took place.

[35]As we describe below, MetaMuse was improved slightly following the first evaluation session. This improved version of MetaMuse was also used to generate the screen-shots that are given in the preceding sections.
[36]Actually a potential end-user, as he was an experienced teacher-composer

Table 6.1[†]

Example 1 of MetaMuse-'Learner' interactions

Agent turn-utterance	Sub-goal (turn)	CA (utterance)	Other (actions)	Commentary and state transition
TA1: 'Was it what you expected?'	target M or Ref	question		state 6 or 8 -> state 9 This is actually fixed on the MetaMuse MainScreen interface.
LA2: Yes	monitoring evaluate	assertion	selects 'Yes' from the pop-up menu.	state 9 -> state 10
TA3: Mentor asked: Was it what you expected? Learner said: Yes.		dialogue management		TA is providing a summary of recent turns. It is only at this point that TA actually 'wakes-up', although the earlier inputs are accessible to TA. It is only at this point that 3 new menu options appear.
TA4: OK, you think it worked. Try choosing 'diagnose the phrase' from the respond menu and say why you think it worked.	target M or Ref	assertion confirmation request		state 10 -> state 9
LA5:	monitoring diagnose		selects 'diagnose the phrase' from the respond menu.	state 9 -> state 10
TA6: Assert your diagnosis below'	<above TA goal still active>	dialogue management	Puts up a help box explaining what diagnose the phrase means and a dialogue box with a prompt 'Assert your diagnosis below'.	
LA7: reasonably accurate planning	<above LA goal still active>	assertion	Enters utterance and then clicks on 'Return it'.	Enters a diagnosis.

[†] TA = Teaching Agent (MetaMuse); LA = Learning Agent

The learner in Table 6.1 is happy with the way the phrase sounded when it was played back, and has hence answered 'Yes' at turn LA2 in response to the 'question' at turn TA1. The learner's reason for this is given at LA7 in the form of an 'assertion' ("reasonably accurate planning"), which is connected to the learner's goals of 'monitoring-diagnose', initiated moments earlier at LA5. The interaction shown in Table 6.1 shows us how the learner and MetaMuse interactions progress through a series of transition states (which are indicated in column 5). The STN being traversed in Table 6.1 is shown in Figure 5.4. Had the learner answered 'No' or 'Maybe' at LA2 or chosen a different 'Respond' menu option at LA5, then subsequent interactions would have differed from those shown in Table 6.2, and would have taken a different route through the STN.

Table 6.2[†]

Example 2 of MetaMuse-'Learner' interactions

Agent turn-utterance	Sub-goal (turn)	CA (utterance)	Other (actions)	State transition
TA8: Good, you seem to be getting the hang of this.	motivation encourage-ment	assertion		state 10 -> state 12
What do you see the function of the very large leap, (12 -20), as?.	critical probing	question		state 12 -> state 26
Select an option from the Respond menu.		dialogue management		
LA9:	critical clarification		selects 'Answer the question'. from Respond menu	state 26 -> state 31
TA10:		dialogue management	Puts up an Interaction Box.	
LA11:	<above LA goal still active>		selects button 'Make a statement about your phrase'.	
TA12: Assert your statement below'		dialogue management	Puts up a data entry box with prompt 'Assert your statement below'.	
LA13: 1. the pattern could not continue upwards and 2. functionally to return to the starting point	<above LA goal still active>	assertion assertion	Enters utterance, returns it, then selects button 'Move on'.	

[†] TA = Teaching Agent (MetaMuse); LA = Learning Agent

In order to achieve the 'critical probing' goal at TA8 in Table 6.2[37], MetaMuse has made use the Perception Machine's analysis of the learner's phrase (i.e. that it uses a

[37]Note that the 12 -> 26 transition at TA8 (which are shown in Figure A8.5 in Appendix 8) misses out transitions 12 -> 13 and 13 -> 31, which in this context made no sense (this was an implementation decision, not an agent choice made at run time).

large leap). The teaching agent is trying to see if the learner is composing in an intentional manner. At LA13 the learner provides 'critical clarification' in response to the teaching agent's probing and makes it clear that he is in fact composing in an intentional manner. The interaction then went on to include more 'critical probing' by the teaching agent and 'critical clarification' by the learner. Figure 6.13 shows the Learner Profile that was produced automatically by MetaMuse at the end of the session.

Learner Profile (please discuss this with your teacher).

1. The learner beliefs (inputs by the learner):
Prediction about phrase - (moving pattern up through octave and above, then returning tobase only to begin again)

Evaluation (initial) -
(The phrase was as expected)

Evaluations made elsewhere in interactions (may be empty, i.e. nil) -
nil
nil

Diagnosis - (reasonably accurate planning)

Imagined opportunity - nil
Paused to reflect on an opportunity on 0 occasion(s)

Critical thinking (the first answer input is at the bottom):
clarification - (
3 Learner response to MetaMuse's probing about Does the large leap segment the music?:
No. it is a component of the complete phrase
2 Learner response to MetaMuse's probing about imagining you are playing the phrase on an instrument:
percussion and high woodwind
1 MetaMuse question 'What do you see the function of the very large leap?'
Learner response: 1. the pattern could not continue upwards and 2. functionally to return to the starting point)

2. MetaMuse analysis of learner's phrase:
(Your phrase uses a very large leap: (12 -20))

The learner's phrase is: (0 8 16 12 -20 0 2 0 1 0 8 16)

3. The learner has refused advice on 0 occasion(s).

Figure 6.13. Example learner profile.

One point to note is that the way that MetaMuse formats critical thinking goals, in the Learner Profile, is a little difficult to understand (this needs improving on in post-doctoral work). MetaMuse points out (in Figure 6.13) that the first question-answer pair for critical thinking goals starts at the bottom of the list (i.e. that 'critical clarification' interactions are displayed in the reverse order to the order in which the occurred in the interactions). To clarify this point, in Figure 6.13 we have inserted bold numbers that indicate the time sequence in which the question-answers pairs took place in the session. It should be also noted that a learner answer may in fact be a further question for discussion with the teacher or a student following the session with MetaMuse (although this is not the case in Figure 6.13).

6.5 Formative evaluation of MetaMuse

The overall aim of the formative evaluation was to gain feedback on the outcome of using the KMf to guide both the analysis of interaction data and design of an agent (the outcome was the pre-prototype teaching agent). The data from this formative evaluation could potentially have also been used to inform the construction a full prototype teaching agent, which could then be evaluated with students (this will be post-doctoral work).

6.5.1 The study set-up

Cooperative Evaluation (Wright, Monk et al., 1990; Monk, Wright et al., 1993) was used in conjunction with a questionnaire as the formative evaluation research approach and method. Cooperative Evaluation (described in Section 4.3) is an approach that places emphasis on a user working through a task and answering such questions as: What will the system do if? What has the system done? Why has it done that? Other approaches to evaluation tend to regard users as experimental subjects.

The specific aim of the evaluation, therefore, was to get initial feedback (by the use of questionnaires) from music teachers and educational technology researchers on six related questions:

1. Details of participants' current post, professional qualifications and experience with music teaching and educational technology.
2. How interesting participants found MetaMuse.
3. How useful participants found the way that MetaMuse promotes creative reflection about a musical phrase.
4. Participants' assessment of the potential that MetaMuse has for assisting in undergraduate composition classes.
5. Participants' assessment of how useful they found the guidance provided by MetaMuse.
6. Participants' assessment of how useful they thought the learning approach used by MetaMuse was for musical composition education (i.e. learning how to make predictions and reflecting on what actually happened).

There were various aims behind the above questions. The second question was used as a general question to catch user impressions of the teaching agent. Another aim of the questions was to see if users felt that the agent could reproduce, at the formal level, interaction that is similar in structure to a human teaching agent whose goal was 'creative reflection' (the third and sixth questions). The prototype, in its current implementation, has no natural language understanding; there is a lot of processing going on behind the scenes (although response time was very fast) and some interface activity. Given this limitation, the fourth question attempts to identify the useability of the system, could it be used in the classroom with students? The fifth question is attempting to ascertain how the participants evaluated the help screens and messages provided by the teaching agent.

The formative evaluation of the pre-prototype teaching agent (the fourth study shown in Figure 1.1 in Section 1.5) was conducted in London and at a Department of Music in a University College in the north-east of England in May and June, 1988. The formative evaluation was conducted with one AI-Music-Education researcher and with four musical composition teachers. The background of each of the five participants in the study is detailed in Section 3.1 of Appendix 10. Four participants were male and one was female. Immediately before the sessions at the music department, participants were played brief extracts, using a digital audio tape player, of performances of students' compositions that made use of the musical pattern Slonimsky No. 1, which is also used in MetaMuse. Each co-evaluation session each lasted between 30 to 50 minutes and was recorded on audio tape (however, with the exception of participant 1, these records remain unanalysed).

The co-evaluator pairs (a participant and Cook) sat in front of a composer workstation, which consisted of a Macintosh Quadra, with MetaMuse installed, attached a midi-device and speakers. Each session involved the participant being asked to carry out a small composition task, details of which are provided in Section 1 of Appendix 10, (10 minutes of the session were set aside for participants to read the notes and ask questions of clarification). Briefly, the compositional task was for the participant to attempt, using MetaMuse, to create a phrase by the repeated chromatic transposition of an initial four note phrase (C C# F# G). When using MetaMuse to compose a phrase, participants were asked, in the task sheet and by MetaMuse, to limit the approach used (when transposing the phrase) to repetition, contrast and trajectory. The reason for taking this constrained approach (of only allowing repetition, contrast and trajectory) was that MetaMuse knows more about how to interact than it does about music (later versions will improve on this lack of musical knowledge). Thus, constraining the types of activities that the composer was allowed to undertake would, it was hoped, give MetaMuse a chance of being able to analyse what the participant was doing (and hence MetaMuse would have to be have a reasonable basis for mentoring interactions).

Participants were informed that the current implementation of MetaMuse could only recognise the following approaches, and were asked to limit themselves to variations on one of these approaches when composing a phrase:

- octave leaps, e.g. 12 24 -48 0 12 -36
- descending trajectory, e.g. 33 12 0 -2 -12 -20

- ascending trajectory, e.g. -20 -12 2 0 12 33
- large leaps, e.g. 0 1 2 40 2 1 0 3 2 1
- repeated transposition, e.g. 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
- small phrase, e.g. 0 1

Each co-evaluator filled in a questionnaire immediately following a session. It is these questionnaires which are used as the basis for our evaluation (Section 2 of Appendix 10 describes the questionnaire that the participants were asked to fill in at the end of a session.)

6.5.2 Results and discussion

Section 3 in Appendix 10 presents the 'incidents' that were identified in participants 1's (taped) Cooperative Evaluation session, and the changes that were made to the teaching agent on the basis of this user evaluation. Consequently, sessions 2 to 5 were conducted with a slightly improved version of the teaching agent. Post-doctoral work will examine tape recordings of sessions 2-5 in order to further improve system design by this iterative process.

Section 2.2 of Appendix 10 provides a transcription of the participants' responses to the questionnaire. Table 6.3 shows a tabulation of participant scores for questions 2 to 6.

Table 6.3

Participant scores by question

Participant	question 2	question 3	question 4	question 5	question 6	total
1	5	5	4	4	5	23
2	5	4	5	3	5	22
3	3	3	2	2	3	13
4	4	4	4	3	5	20
5	5	5	5	3	5	23
Total	22	21	20	15	23	101

The sample size, at 5, is small and so some caution is required when attaching significance to these results. Given this reservation, however, the results seem favourable, the average response score was 4.04 (out of 5). We will now discuss the above results in the context of the underlying purpose of the questionnaire, which was outlined in the section above (6.5.1).

Impression of the teaching agent (q2).

With a score of 22 out of 25 the overall impression of MetaMuse seems favourable. The comments made by participant 5 (a former head of department of music) were encouraging:

> Compositional value in teaching very useful. Patterns are quite limiting - which make a good test of both 'learning' and 'ingenuity'. It would be further use in teaching to [be able to] play around with the pattern (invert, retrograde) and with tempo.

Participant five's ending comments echo participant three's ("Needs a musician friendly front end"), i.e. that the system needs further work.

Were the interactions able to promote 'creative reflection'? (q3 and q6).

The scores of 21 out of 25 (for question 3), and 23 out of 25 (for question 6) we feel are further indicators that MetaMuse is 'on the right track'. However, one comment made against question 3 recognised the need for a more sophisticated analysis of what has already been said by the learner, in order to avoid repetition:

> It would probably be more helpful if it were able to pick up on key words in the responses and therefore not ask questions which have already been answered. However, the process of evaluation is useful, although I'd be interested to see how it coped with larger structures. (Participant 4)

The issue raised in the ending of participant four's comment above ("I'd be interested to see how it coped with larger structures") was also picked up by participant 5 ("Needs to explore further how small components can contribute to a larger frame (structure : form)"). Future work could develop MetaMuse's ability to work with larger phrases and sections.

However, the responses to question 6 (which received the highest score for any question, at 23 out of 25) was very positive, and as such are reproduced in full below:

Participant 1: Was very informative to make and evaluate predictions. I didn't expect to be wrong. Perhaps guide learner to be more detailed (i.e. committed to their predictions ...). Without guide to ascend and use contrast, etc., I wouldn't have known where to go.

Participant 2: Except on a one to one basis, I cannot imagine any other way of achieving this experience. This does test and help develop memory and critical thinking in a relatively non-threatening manner.

Participant 3: Most undergraduates would be at too high a level. Better on Primary/Secondary.

Participant 4: Overall, I think this could be very useful in terms of a learning tool in encouraging students to think about both local events and (potentially) larger scale events; and the process of constructing events to create cohesive work.

Participant 5: Excellent introduction to awareness of sound.

Interestingly participant 3 (who was the only participant not to give question 6 a score of 5 out of 5) is not actually a composition lecturer, unlike participants 2, 4 and 5, who do teach composition at undergraduate level and who do see the 'full' potential for MetaMuse to teach creative reflection.

Could MetaMuse be used in the classroom with students? (q4)

Opinion on question 4 seemed to be split between those who do not teach composition (participants 1 and 3, who thought that MetaMuse may be appropriate in schools) and those who do teach composition (participants 2, 4 and 5, who thought it would be useful for first year undergraduates). If MetaMuse were given more domain knowledge then we feel that it would appear more convincing. Of course, MetaMuse would have to be more convincing in terms of its domain knowledge if it were to be evaluated with students (who might take the same view of MetaMuse as participants 1 and 3). Improving MetaMuse's domain knowledge would provide an interesting project for future work.

Evaluation of the help screens and messages provided by MetaMuse (q5)

This question received the lowest score (15 out of 25). The help screens and the language used by MetaMuse clearly need improving. Participant 2 (when actually answering question 2) probably put his finger on the weakness of the help screens and messages:

> The language and display of text needs a radical rethink! A session with students on the language used would be essential - and a good thing to do anyway as this kind of formal language use is not (but should be) encouraged.

Furthermore, we would agree with participant two's comment in response to question 5 that

> As it stands this system's guidance messages and information would best be read by a pair of students who could together deliberate on the text.

The use of a full prototype MetaMuse by pairs of students in the classroom would make an excellent line of inquiry for future work.

6.6 Summary of computational approach

In summary, the design, implementation and evaluation of a pre-prototype human-machine dialogue system called MetaMuse has been described in this chapter. MetaMuse was integrated with Coleridge and was also based on both an extension of an existing computational model of rational agents (Blandford, 1991) that is capable of engaging in dialogue, and the results obtained from qualitative and quantitative analysis of the dialogue corpus (i.e. Section 5.4). We extend Blandford's work both by using empirically derived state transition networks as the basis for planning (Blandford's agent does not perform any planning) and by applying the agent based approach to mentoring in the domain of musical composition.

In the computational model of our teaching agent, an action cycle is used to determine what communicative actions to make at each time increment of a session. When it is the teaching agent's turn, it generates a list of wants that are available to it at the current node of the STN. The agent then uses a preference mechanism to select the want that best meets its current situation (i.e. the agent tries to become 'committed' to one sub-goal). Appropriateness conditions are used to define the conditions under which a sub-goal can satisfy a pedagogical goal. Furthermore, the degree to which each sub-goal or action meets the agent's values is specified by (empirically derived) preference weightings. Once committed to a particular sub-goal, the agent forms an intention to take action. Before eventually making a communicative act, the agent may use a move function to perform some local adaptation of its utterance.

Our computational implementation, i.e. the pre-prototype MetaMuse described above, is limited in what it can do. MetaMuse is able to structure the interactions with a learner in a way that promotes reflection (this was a formative evaluation finding). MetaMuse can only deal with a small task and can not understand natural language. However, within certain limitations, the system is able to comment on a musical phrase input by the learner.

The objective of the formative evaluation of MetaMuse, also described above, was to evaluate with users the system that has been developed as a result of a process of "human-teacher-student-dialogues and theory to design", before going on to the next stage, which would be to "refine" the system. Hence, the formative evaluation focused on eliciting user opinions on the current version of MetaMuse. In the case of participant 1, however, we were able to examine the taped interactions and improve the system design in time for the other four co-evaluations (which all took place within 2 days of each other). Beyond this very small iteration of the "evaluate-refine" aspect of User Centred System Design, no further system development (coding) took place. The evaluation showed that MetaMuse has the potential to promote creative reflection in learners.

Chapter 7 - Contributions, Conclusions, Limitations and Future Work

The main research question addressed in this thesis (which was stated in Section 1.1.3 of Chapter 1) was: how, or to what extent, can studies of dialogue and interaction be exploited in a concrete way by designers of teaching agents? We have, in this thesis, described in great detail how theory and empirical data from interaction analysis have been used to both develop a computational model and to implement a computer-based teaching agent. An evaluation of the teaching agent showed that MetaMuse has the potential to promote creative reflection in learners. This finding supports the argument being made in this thesis (at least within the limits of our own empirical and evaluation studies): namely, that an iterative approach to user-centred design of teaching agents has been developed (and demonstrated to work in at least one case). We expand on this thesis contribution in Section 7.1 below. This is followed, in Section 7.2, by some conclusions on the implications, of the work presented in this thesis, for music education and AI-ED. Section 7.3 then discusses the limitations of our research. Finally, Section 7.4 provides suggestions for possible future research directions of this thesis work.

7.1 Contributions made by this research

The contribution of this thesis is an original, user-centred framework that provides an iterative approach to designing computer-based teaching agents in problem-seeking domains that is based on a principled and systematic relationship between theory, empirical data, computational model and computational implementation. We claim that the phenomenon of mentoring exists in at least one case (i.e. the empirical study), and that this is a possible behaviour that a system could have to deal with (this will be extended in future work). Consequently, this thesis makes the contribution of a system design approach that relies on descriptive models based on observations of humans interacting. The components of our contribution are as follows:

- The Knowledge Mentoring framework or KMf, a theoretical framework for linking interaction analysis to teaching agent design that has been empirically validated. The KMf provides a taxonomy and definitions of the pedagogical goals involved in a mentoring style of teaching and a convenient tool for the analysis of protocol data in terms of communicative acts and associated goals. The KMf gives a single composite and coherent contribution that links theory, data and computational model to a teaching agent design approach for mentoring interactions. This framework also includes a clarification of some educational mentoring principles as applied to the problem-seeking domain of musical composition.
- Coleridge, a computer-based learning environment that provides the materials for creative reflection that was developed in collaboration with a composer-teacher.
- Detailed empirical findings that answer some specific research questions. The systematic analysis and interpretation of the data went further than proving the adequacy of the theoretical framework (the KMf); it generated several new results which, we propose, would be useful in the design of a computer-based teaching agent.
- MetaMuse, an empirically based pre-prototype teaching agent that incorporates a model of mentoring interactions and attempts to develop a simple user model of a learner's attempts at creative reflection (i.e. metacognition). Furthermore, a limited attempt was made to formalise musical knowledge in a component of MetaMuse. An evaluation of MetaMuse with users showed that it can promote creative reflection in learners. This finding supports the validity of the contribution being made in this thesis (subject to the limits of our empirical study described in Section 7.3). MetaMuse, differs from other ITS dialogue models in that no other systems have been reported for promoting creative reflection about musical composition in higher-education.

7.2 Conclusions on impact of this research

7.2.1 Implications for musical education

The first step on the road to the development of MetaMuse was an attempt to 'sound out' leading music educators, who were asked the following question in a small survey (Appendix 1):

> Have you, or has anyone you know of, followed up your study/work by examining in detail the meta-cognitive/reflective thinking of the following?
>
> Composers as they reflect on their work,
>
> learners as they reflect on how they are being taught,
>
> teachers as they reflect on how to teach composition.

Some of the replies to this question (which are given in Appendix 1) were contentious and may cause debate within the music teaching community. If we examine the quote in our survey form John Paynter (someone that most music educators will know of), we can see that he viewed the topic chosen for investigation in this thesis to be of central importance to music composition education:

> "... you will know that this field [musical creativity], is a field I have worked in for close to 40 years. Everything that I have done has been towards helping children (and adults) to develop the capacity to reflect upon their experiences (of music's affective power) ... I do not accept that the Swanwick/Tillman "sequence" tells even half the story; but I know of no systematic study of the kind you mention."

> "I have to say that, having taught in the way I do for so many years ... I have no hesitation in saying that all the evidence points to (i) the development of reflection upon what is made by those who make it (ii) 'reflection' of the kind we have in mind is an essential part of the teaching process which cannot work otherwise (iii) the most successful teachers <u>must</u> develop the skills of

reflection and speculation in their pupils because composition is, by its nature, an analytical process."

Paynter's approach is very similar to the aim of the study described in this thesis, namely our exploration of the interactive means by which a teacher promotes creative reflection in learners. We would agree with Paynter when he points out that "the most successful teachers must develop the skills of reflection and speculation in their pupils". Clearly there is no one correct approach to teaching musical composition, and this work has explored only one approach. However, the notion of 'reflection and speculation' is close to the idea of creative reflection being proposed in this thesis (i.e. speculation is similar to problem-seeking and 'imagining opportunities').

Thus, the 'systematic study' of teacher and learner reflection, presented in Chapter 5, should be of interest of music educators. This empirical work describes in detail how one music educator promoted 'reflection and speculation' in four separate sessions with student composers. A computer-based system that attempts to promote similar types of reflective engagement to those observed in the study has been developed. The system, called MetaMuse, appears to have the potential for use in the music classroom. The formative evaluation of MetaMuse involved various music educators. As Section 6.5 shows, MetaMuse received a favourable evaluation from these practitioners (even in its pre-prototype form). Here is one comment from a composer-teacher, and a former Head of Department of Music, in the study (this is part of participant five's response to question 2, which asked "How interesting participants found MetaMuse."):

> "Compositional value in teaching very useful. Patterns are quite limiting - which make a good test of both 'learning' and 'ingenuity'."

Furthermore, MetaMuse has the ability to provide a Learner Profile that can form the basis for further reflective engagement and dialogue with fellow students or with the teacher. This ties in with one approach to supporting reflection and speculation about music (Auker, 1991). Auker has suggested that students should be allowed to develop the appropriate spoken language by interacting with each other. They can then adapt and take ownership of this language as they begin to internalise and 'reflect' on creative opportunities, and hence build the appropriate mental structures of their creative intentions. It appears, therefore, that MetaMuse has the potential for integration into the musical composition classroom as a facilitator of this spoken musical language.

7.2.2 Implications for AI-ED

This section discusses some possible practical uses of the work presented in this thesis. Specifically, this section explores the implications of our theoretical, empirical and computational work for student modelling and diagnosis, instructional planning and descriptive-prescriptive models of decision making.

7.2.2.1 Implications for student modelling and diagnosis

Student modelling is one of the basic mechanisms by which an AI-ED system can individualise interactions to a particular learner. Within Intelligent Tutoring Systems, student models are mainly used to support the learning of content; whereas within ILEs a student model would be used to manage the learning process and to ensure that learners engage in the desired metacognitive processes of monitoring and reflection (Self, 1992).

In Chapter 1 to this thesis, we have already described how a DORMORBILE-like student model (Self, 1992; Self, 1993) would be structured for musical composition. Although this explanation was given in order to clarify the difference between musical cognition and musical metacognition, in doing this we also provided an indication of what facts, knowledge and processes would be found at each of the four levels; in addition we described how musical knowledge might be 'compiled down' from a higher level to a lower level as a learner becomes familiar with what is being learnt.

The Learner Profile, described in Chapter 6, represents the combination of a belief structure and simple User Model output by MetaMuse as the Leaner Profile, i.e. (TA believes (model of LA)). The implication of generating the Learner Profile is that the teaching agent is seen as a tool that is to be integrated into the classroom in order to promote further learner dialogue and reflective engagement. These types of dialogues can occur when the teacher discusses the Learner Profile with the student, or when students discuss their profiles with each other. A similar approach could be adopted in other domains, where we could potentially get lots of loops around the cycle of the learner interacting with the teaching agent, then discusses the profile after using the system, and then interacting with the teaching agent again. As such, MetaMuse links into the collaborative learning work in AI-ED (Baker and Lund, 1996, for example).

Although the SE Coach (Conati, Larkin et al., 1997, reviewed in Chapter 2, Section 2.2.2) appears in agreement with our own research position (that time is needed by a learner to explain and reflect), no precise definitions of low viewing time (of a domain related problem) or high viewing time are given by Conati et al. The process of forming and updating the student model by analysing data made available to the system is often called diagnosis. The empirically generated values related to pauses (Table 5.5 in Section 5.4.2) could serve as a diagnosis metric to govern teaching agent inference about how well a learner is doing. This analysis of the different functions of pauses can be used as one source of evidence, although not infallible, for the extent to which the students are actually engaging in reflective activity (creative reflection). If the SE Coach were applied to musical composition learning, and assuming that some of the formidable problems related to supporting self-explanations in the open-ended, problem-seeking domain of music had been solved, then the some of the empirically derived values from our own empirical study (albeit a small sample) could serve as values to govern agent inference about how well a learner is doing. For example, the pause scores shown in Table A4.3 (Appendix 4) appear to be good indicators of student ability. If a student has a score of zero for some goals (e.g. student 2 in Table A4.3, Appendix 4) then more focused mentoring using critical probing may be called for.

Bull and Broady (1997) have found that students who are allowed to share each others' student model will often spontaneously collaborate or tutor each other and subsequently may develop a deeper understanding of the target domain. However, Bull and Broady also found that in some cases performance scores decreased. The reasons for this are unclear. Bull and Broady speculate that this may be due to a stronger partner not wishing to appear too dominant. One result presented in this thesis has suggested that student and mentor engage in reciprocal modelling, i.e. they build models of each other, and that this can have a varying effect on performance. These models could be made explicit in the manner described by Bull and Broady by using an approach to partner modelling proposed by Bunt (1989). This approach to partner modelling is now described.

Reciprocal modelling was identified in 2 out of 4 of the sessions (Chapter 5) using the post-experimental cue technique (it may have happened in all four session, a question that would have ascertained this was simply not asked in 2 cases). In session 1 the learner had a goal of causing surprise. In session four the learner's goal was to do what was expected of him, but with increased intensity. By adapting Bunt's (1989, pp. 55) approach, we can specify the following appropriateness condition, i.e. we can say when it is relevant to develop a particular model, for 'partner modelling' of the teacher from the learner's perspective. The general model of appropriateness conditions of partner modelling is shown in Figure 7.1.

In Figure 7.1 LA is the learner, TA is the teacher, p is a proposition, know and suspects are attitudes (that do not make a commitment to the actual truth of p), and intends is an imminent commitment to action. By taking the session 1 example, we can put the Appropriateness Condition (AC) in parentheses to illustrate the Move Function (MF) of partner modelling. ACs are the conditions under which a tree branch in Figure 7.1 is taken.

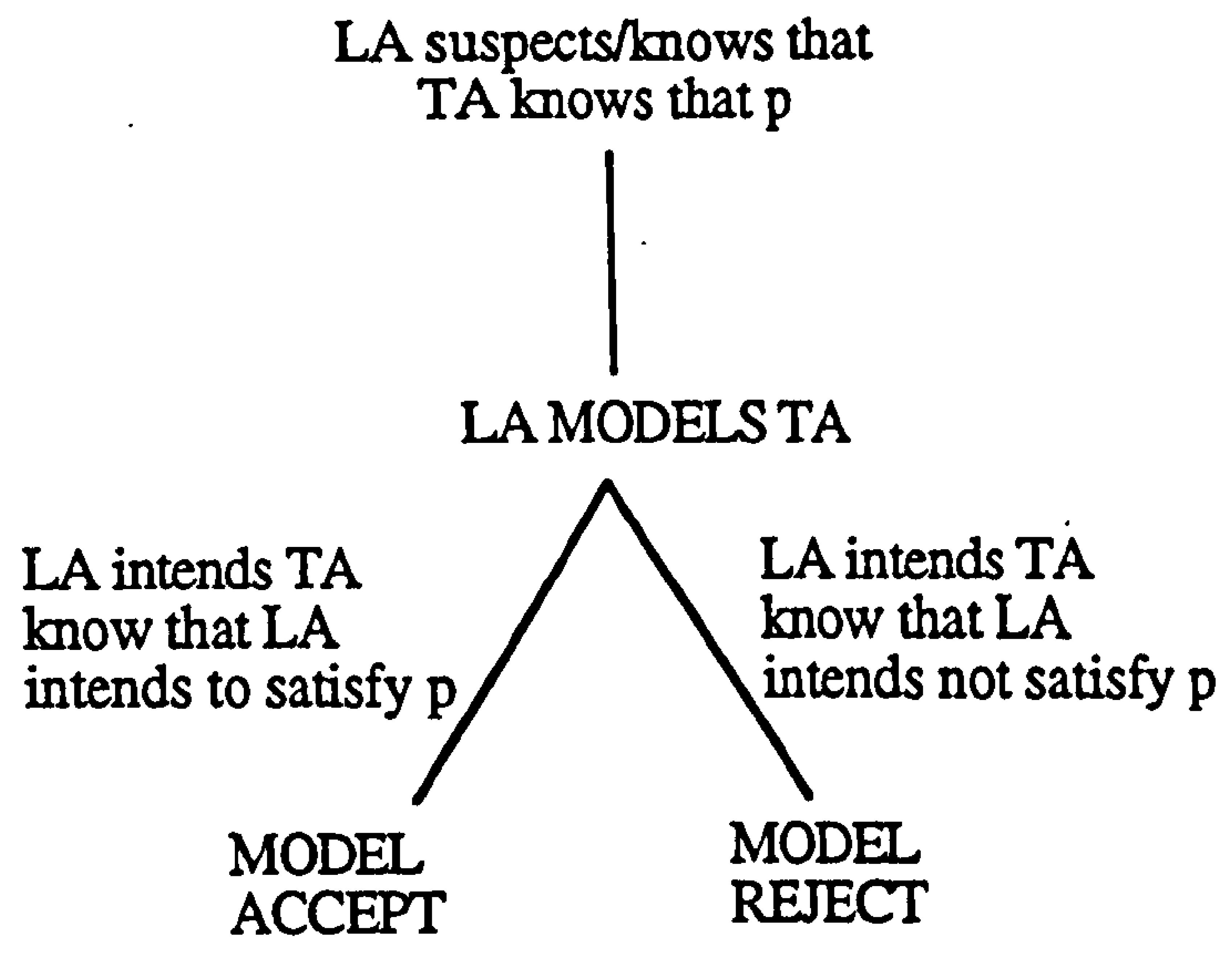

Figure 7.1. Appropriateness conditions of partner modelling

MFs were described in Section 3.2; they define the purpose of a communicative act in a specific context.

Partner modelling example 1

1. I thought at first, when he said tempo, I thought 'he's thinking that

AC[LA suspects]

2. that I would like it slower',

AC = [that TA knows that p]

MF = LA MODELS TA

3. would I like it slower? And thought about it, and my answer was that I actually think that it would be better faster.

AC = [LA intends TA to know that LA intends not satisfy p]

MF = MODEL REJECT

Step 3 above eventually led to the communicative acts of 'question' at LA7 and the 'request' shown at LA8 in Table 4.1 (Section 4.2). For the session 4 example, the partner modelling is as follows:

Partner modelling example 2

1. So now when [the mentor] says: 'Make it more irregular',

AC = [LA knows that TA knows p]

MF = LA MODELS TA

2. I go out of my way to make it more irregular.

AC = [LA intends TA to know that LA intends to satisfy p]

MF = MODEL ACCEPT

The above approach to understanding of an utterance, both for its content and its function, has been used by Bunt in the TENDUM dialogue system (Bunt, Beun et al., 1985). In TENDUM move functions (Bunt et al. call them communicative functions) play a role in two places: in the interpretation of natural language inputs, and in the planning of a continuation of the dialogue. What we are proposing here (as one implication of our empirical work) is a combination of Bull and Broady's and Bunt's work. A teaching agent could be used to interact with the learner to develop a set of partner models. The teaching agent could model the learner, i.e. (TA believes (model of LA)). The teaching agent could also develop a model of what it suspects the learner's model is of itself, i.e. (TA believes (LA believes (model of TA))). There are two reasons for doing this modelling. First, both models could be used to influence TA's next turn and utterance choice (Ndiaye and Jameson, 1996). Second, the agent could allow pairs or groups of students to come together to discuss each others' model set. The first proposed reason for modelling is discussed further below. One problem with the second proposal is that learners are not always good at explaining their internal processes. However, this is exactly the type of interaction that we wish to encourage with agent-based ILEs. Getting students together to collaboratively explain their partner models may encourage reflective engagement. What we are proposing is that the teaching agent should not be viewed as a stand-alone resource, but as an assistant to be used in the classroom.

Another interesting link, between the result about the occurrence of reciprocal modelling and the student modelling that can be pursued is the AI research, mentioned above, on nested (look-ahead) modelling (Ndiaye and Jameson, 1994; Ndiaye and Jameson, 1996). Ndiaye and Jameson (1994) address the issue of making their natural language processing system, called PRACMA, 'transmutable', i.e. where the system is able to take on either of two possible roles in a dialogue. Transmutability would, the authors claim, enhance the system's ability to anticipate and interpret a dialogue partner's reasoning and behaviour. PRACMA models noncooperative dialogues between a buyer and a seller and includes a module that makes use of Bayesian meta-networks for reasoning about the dialogue partner's beliefs and evaluations. Clearly, such an approach would be useful because, as we saw above, a student may decide to be cooperative or noncooperative, depending on the way in which they decide to model the teacher (the learner may decide to accept or reject what they think the teacher wants from them).

We can envisage two instances when priority should be given to look-ahead modelling. First, the predicting of possible dialogue turns and utterances is similar to our notion of creative reflection, where LA is being asked to predict how a phrase will sound before it is played back. A computer-based teaching agent that was able to develop its own partner models of creative reflection a few moves ahead, based on a learner's musical input, and that was able to share this model with a learner would be a convincing agent. The second priority to look-ahead would involve diagnosis of 'entrenched' partner modelling. The first session in the empirical study was deemed by the mentor as more successful, possibly because he valued surprise. Of course, surprises have to be the right kind of surprises! One implication for look-ahead modelling is that learners should not be allowed to become too 'entrenched' in reacting on the basis of one model (i.e. the learner's model of the teacher). We have already pointed out above that, although the student in session 4 in the empirical study appeared very capable and indeed outspoken, his stated goal of going "out of my way to make it more irregular" may have been counter-productive. In this case it would appear that the learner's modelling of the teacher's expectation influenced the student's decisions in a negative way. Session 4 accounted for all 13 occurrences of 'not accept yet' shown in Table 5.3 (Section *5.4.1), which is where the learner does* not appear to accept the validity of the tutorial 'task' or 'offers' made by the mentor on how to proceed in the session. Of course, this finding is tentative. If entrenched modelling was detected by the accumulation of utterances like the category 'not accept yet', then the agent could perform deep 'look-ahead' modelling to find the best combination of turns and utterances to encourage the learner to develop a new model.

7.2.2.2 Implications for instructional planning

Instructional planning has recently been defined as an attempt to orchestrate the activities of the learning environment (Wasson, 1996, p. 28). Specifically, instructional planning is now perceived as technique to support the individualisation of the learning activity. It may involve a process of

> "mapping out of a global sequence of instructional goals and actions that enables the system to provide consistency, coherence, and continuity throughout an instructional session and enables this global sequence to be interspersed with local goals generated when instructional opportunities arise ...". (Wasson, 1996, p. 24)

The goals and plans are used by the system to indicate what instructional strategy is required given the current state of the learning environment. An interesting link exists between the state-transition networks resulting from the empirical study described in this thesis and the approach for instructional planning used in MENO-tutor (Woolf and McDonald, 1984). MENO-tutor uses a Discourse Management Network (DMN) to plan instruction. The DMN (or tutoring component) "contains 40 states similar to the state of augmented transition network, or ATN" (Woolf and McDonald, 1984, p. 68). The nodes in the ATN correspond to tutorial actions that constitute the basic components of a theory of tutorial dialogues. The DMN makes decisions about what discourse transitions to make and what information to convey. The DMN is a "set of decision units organised into three planning levels that successively refine the actions of the tutor" (Woolf and McDonald, 1984, p. 67). These three levels have hierarchical dependencies (actions at one level may be a refinement of actions at the level above). The arcs of the DMN define the sequence of states normally traversed by the tutor. State transitions thus correspond to default tutorial paths. A set of metarules are also provided that can, if triggered, move the focus to any state in the network.

MENO-tutor made a useful attempt at the development of domain independent discourse planning. Woolf and some co-workers (Woolf, Murray et al., 1988) have used Tutoring Action Transition Networks that are similar to the DMN as a control tool for facilitating the specification and modification of prototypical patterns of tutorial behaviour (this work was reviewed in Section 2.3.2). However, the following issues have been raised regarding the DMN. First, Wenger (1987, p. 256) has noted that in MENO-tutor the articulation of the teaching principles upon which decisions are based are not explicitly represented. These principals are implicitly embodied in the arcs and metarules of the DMN. Douglas (1991) has also pointed out that the DMN, and related later work by Woolf, proposes a structure for discourse that is largely independent of the pragmatics of the particular context: "Thus, the history of the discourse, the student (hearer) model, and the tutor's (speaker's) intentions are informally implied" (Douglas, 1991, p. 128). Douglas in fact makes a similar point to Wenger: that the DMN can say whether a particular set of state transitions should occur, but is unable to explain why they should occur at that point in the dialogue. If an approach to using transition networks is to be generalisable to other domains, then the question of 'why' a particular exit from a node is taken needs addressing. Furthermore, the requirement to know 'why' a particular intervention (i.e. choice of transition) is appropriate is particularly relevant in the case of an Intelligent Learning

Environment, where an agent needs to reason dynamically about appropriate actions to manage the learning process in a particular situation.

One result of our empirical study was State Transition Networks (STNs) for the seven mentoring stages. In our approach the arcs represent sub-goals, which may lead to action or communicative acts. The nodes represent a state at which a decision is made about which transition should be selected next. These STNs can be used to structure interactions and to embed those interactions in computer systems. A prototype teaching agent, described in Chapter 6 has been implemented on the basis of this approach. The networks were used in MetaMuse to provide means-ends beliefs about which goals satisfy a particular mentoring stage. Often, more than one exit was possible from a state node. A way of structuring interactions would be to offer these options to a learner as a menu (the options would vary from one node to the next). Preferred options are highlighted by MetaMuse. Thus, the STNs used in our computational model and computational implementation (MetaMuse) are principled in that the STNs represent descriptive abstraction of what one teacher actually did with four students. We believe that our approach to using the KMf to guide both the collection of STNs and their incorporation into an ILE has wider applicability. We can imagine this approach being employed in domains as diverse as health care education and fine art.

7.2.2.3 Implications for models of decision making

This section addresses the issue, raised in Chapter 1, of whether it is in principle appropriate to apply descriptive frameworks (like the typical mentoring STNs and the script identified as results in this thesis) in prescriptive way to guide system design.

This issue of taking descriptive basis for system design can be restated as the question: What is the nature of the argumentative link between the analysis-description of what a human teacher did and the design of a system? The relation can not be one of direct transfer of expertise, for a number of reasons. On the purely dialogue side, you have open-ended spoken dialogue versus constrained human-computer dialogue. And then, artificial agents are not meant to be copies of human ones. As was pointed out in Chapter 1, the interaction analysis framework and the study described in this thesis are part of a teaching agent design approach, described in this thesis, that aims to make practical use of empirical research in teaching agent development. We argue, therefore, that because very few studies have examined how to develop an artificial agent in this way (i.e. to systematically link empirical data to agent design), the best starting point is to look at what human teachers do, and to then implement descriptive models of that. Refinements to the agent and to guiding theories or frameworks (e.g. the KMf) can then take place on the basis of what happens in the real target dialogue environment when students use the system. Any refinement would thus take place as a result of formative evaluations.

Whilst the preference weighting method used in MetaMuse only gives a numerical weighting, it has been used with the STNs described above (which provide means-ends beliefs about which goals satisfy a particular mentoring stage). Our approach (the KMf) to developing empirically based teaching agents has been partially validated by a favourable evaluation of MetaMuse with users (see Section 6.5).

7.3 Limitations of the research

The practical limitations of the work presented in this thesis can be summarised as follows:

- In the KMf we took the decision to use a limited number of communicative acts in an attempt to gain future computational advantage (i.e. to reduce complexity and hence increase the potential for the goal trees to be implemented in a teaching agent).
- A pre-prototype teaching agent was implemented that is limited in what it can do because it only incorporates one or two features of a full system.
- The teaching agent has very limited, fixed expertise in the domain of musical

composition (it does not learn about the domain).

- The formative evaluation of the teaching agent highlighted the fact that the help screens and the language used by MetaMuse need improving.
- For the learner's turn, the options available in the Respond menu of MetaMuse are dictated by the learner exit transitions for the currently active state node. These exit choices were derived from interactions that were observed in the four sessions of our empirical study. Potentially, therefore, by allowing the learner to choose one of these options in the Respond menu, MetaMuse might allow a learner to do something that a student in the study did; but that student in the study may not have done particularly well. However, MetaMuse does make recommendation if it has got evidence that something *would be advantageous to* the student. Furthermore, MetaMuse keeps a count of the number of times advice is refused and attempts to act if advice is persistently ignored.
- In this thesis the empirical study presented had a very small number of subjects. There were only four students and one teacher in the empirical study described in Chapter 5, although an earlier classroom study and pilot study increases the number of students observed to 10 and the number of teachers involved to 2. If we add in the subjects from the formative evaluation described in Chapter 6, then the total number of different users involved in this thesis' empirical work was 16 (one particular teacher was involved in studies 2, 3 and 4 and is therefore only counted once). *Thus, caution must be exercised when attempting to make generalisations to a wider population,* although 16 participants in a user-centred piece of research is starting to look 'healthy'. Our goal has been to describe a limited set of phenomena, and to then take this as the starting point in a design process.
- Also, in the empirical study all the students were following an electro-acoustic route through their degree (i.e. they were not studying tonal music as such). In the empirical study we were dealing with tonal concepts related to transposition. However, all subjects were also taught tonal structures and already had A level music (and will have therefore been familiar with tonal concepts being explored

in the empirical study).

- A limitation of our approach to teaching agent modelling is that it does not represented explicitly a fine-grained user model of user misconceptions.

7.4 Future research directions

Future work could revolve around the following areas.

- Communicative acts in the teaching agent can take the form question, offer, assert, etc. or they may be musical actions (playing a phrase) for the learner to comment on. The form that an act takes is governed by move functions for those circumstances. Only one example of this theoretical feature was actually implemented. Implementation of move functions would make a good line of future work in the short term.
- Extensions to the computational implementation that aimed to improve the re-usability of the approach (in implementation terms) would required the construction of an object-library.
- The computer agent does not attempt to assess 'creative imagine opportunity'. The design specification in Chapter 6 suggested that MetaMuse would instead rely on learner self-assessments. This aspect was not implemented, but could be relatively easily.
- On the basis of feedback gained in the formative evaluation it is clear that the interface (help screens, menus and the interaction language) used by MetaMuse needs improving. For example, if the teaching agent has suggested that the learner should select a particular option from the respond menu, then the suggested option could be highlighted (however, the efficacy of doing this needs further work).
- The findings of the initial Cooperative Evaluation described in Chapter 6 could be used to inform the construction a full prototype, which could then be evaluated with students.

- Other different types of educational experiments that could be done (e.g. learners and teachers studying the Learner Profiles). We could get the teacher to discuss the Learner Profile with the learner, or get learners to work in pairs, and see if there are any improvements in scores for 'make accurate prediction', and related creative reflection goals.
- Often, more than one exit was possible from a state node. Interactions were structured in MetaMuse by offering these choices to a learner as menu options. Preferred options were sometimes indicated to the learner. However, one unimplemented design feature of the teaching agent was that some limited negotiation would take place if a learner did not accept a teaching agent recommendation. This design feature could be implemented.
- Both qualitative and quantitative data could be gathered about student use of the full prototype teaching agent in a summative evaluation. Control studies could be carried out using slightly different versions of the prototype to try and isolate the effect of specific components on the learner. For example, in the agent that was implemented (see Chapter 6), preference for particular intermediate goals could be changed.
- Future work could develop MetaMuse's ability to work with larger phrases and sections. Improving MetaMuse's domain knowledge would provide an interesting project for future work and provide an agent that was more 'convincing' to students. However, the effect that this extension to the domain knowledge would have on the form of mentoring interactions that would then be supported is not clear. Extensions to other areas of music and/or other domains could be considered.
- An interesting line of research would be to use different teachers on the same task (as that used in our study) to see if they were as active as the teacher used in our study, and to develop a taxonomy to inform the best place in the interactions to make a musical act.
- New work could confirm the role of pauses in creative tasks.
- Future work could investigate what the score for intercoder reliability would be if

several coders were allowed to look at the data.

- Additional work could be undertaken to confirm that the approach to empirically derived descriptive models of decision making (described in Chapter 6) has applicability to other domains.
- Representing explicitly a fine-grained user model of user misconceptions could be the subject of another research project.

The generalisability of the KMf would be a problem if we were claiming that one journey around the user-centred design cycle (theory to corpus to agent) were the full story. We are not claiming this. However, what we are claiming is that an iterative approach to user-centred design of teaching agents (in problem-seeking domains), that is based on a principled and systematic relationship between theory, empirical data and system design, has been developed. As is pointed out below, we fully intend to use the formative evaluation findings, described in Chapter 6, as a source of new data to enable us to go around the design cycle again in future work.

For the KMf to be readily generalisable to other areas, like the teaching of social sciences, then we would probably need to exclude the sub-goal, in our framework, relating to 'creative imagine opportunity' and replace it with sub-goals relating to, for example, inter-subjective understanding (see Goodyear and Stone, 1992). Goals relating to metacognitive and critical thinking would, however, appear to be particularly relevant to the domain of social sciences. The KMf may, therefore, have the potential for application in other domains that rely on aspects of creative, metacognitive and critical thinking. Future work will give priority to a focus on both (i) implementing a full prototype teaching agent and then evaluating the agent with student users (short to medium term), and (ii) on testing the generality of the KMf approach to interaction analysis and teaching agent design by applying it to other problem-seeking domains. The latter should take this researcher into projects spanning the medium to long term.

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Glossary of Musical and Agent-Theoretic Terms

Many of the musical terms are taken from Scholes (1970).

Affective attitudes - Include pleasure, liking and value. Kiss argues that such attitudes are important, because autonomy in agents is vitally dependent on the presence of some mechanisms through which the agent is able to adopt its own goals. Agents can take attitudes, such as 'liking' and 'disliking', in situations in which hedonic states (not attitudes) occur.

Agent - An agent is a human learner or a computer-based teacher, 'it' will be used to refer to an agent. An agent is understood, in this thesis, to be an integrated natural or AI system where, in order to satisfy their values, agents derive goals from them and then form intentions to take action to reach these goals. Furthermore, an agent is considered to have each the four levels of DORMORBILE .

Attitudinal state - an agent has three classes of attitude: cognitive, conative, and affective. Kiss suggests that an agent architecture needs to support these different classes of attitudes in order to support the requirement for action (conative), re-action to the environment (cognitive) and autonomy (affective)

Cadence - Nowadays any melodic or harmonic figure which has come to have a conventional association with the ending of a composition, a section, or phrase is called a cadence. Perfect Cadence is the succession of the two chords dominant-tonic (soh-doh).

Cognitive attitudes - The main cognitive attitudes in Kiss' framework are knowledge and belief. An agent can be said to know a proposition P, if whenever the agent is in state S, P can be asserted about the world. Beliefs are held to be true by a given agent. Kiss regards beliefs as uncertain knowledge, i.e. approximations to knowledge because it has limited support (reasons).

Commitment - An agent can become committed to action to, say, achieve a goal. A commitment may or may not be conditional.

Composition method - We are using the term compositional method in a very broad way and define it as the use of concepts, devices and techniques within the context of a framework. E.g. the use of dramatic shape or melodic motive to aid compositional form.

Conative attitudes - The main attitudes in this category are wants, commitments, goals and intentions.

Creative reflection - is a specific type of metacognition that has been developed for the purpose of this thesis. Creative reflection is defined as the ability of a learner to imagine musical opportunities in novel situations and to then make accurate predictions (verbally) about these opportunities. For definitions of related pedagogical goals see Appendix 2.

D (Domain) level - will provide a vocabulary for discussing problems relevant to the domain of music composition. Domain knowledge at this level will be a subset of what is "known" about the domain of music composition.

DORMORBILE - DOmain, Reasoning, MOnitoring and Reflection Basis for Intelligent Learning Environments, distinguishes four levels of agent knowledge for student modelling purposes.

Goal - A goal is a state of the world which an agent explicitly desires to achieve, preserve, avoid, or destroy.

Harmony - It is the chordal aspect of the combination of voices or parts which is properly described as the element of harmony.

Intentions - An attitude towards an action, possibly specifying some commitment by the agent to carry out that action.

Interaction analysis - is often used in this thesis, rather than the more common dialogue analysis, because it includes linguistic communication (i.e. speech) and non-linguistic forms of communication (e.g. musical actions that have communicative intent or actions like pointing at the computer screen).

Interval - By an interval in music is meant the difference in pitch between any two notes.

Intelligent Learning Environment - or ILE refers to a particular type of agent-based learning environment. ILEs emphasise the role of higher-order thinking and have an objective of engaging the student in some goal-directed, problem solving activity that the ILE 'knows' something about (known in the sense that it is believed to be correct). ILEs place a stress on learning by reflection, i.e. metacognition.

Knowledge Mentoring framework - or KMf, provides a taxonomy and definitions of the pedagogical goals involved in a mentoring style of teaching and a convenient tool for the analysis of protocol data in terms of communicative acts and associated goals.

Likelihood - The chances of successful achievement of a goal.

Melody - Melody has been called the surface of music, it is what catches the ear.

Metacognition - can be defined as the understanding of knowledge, an understanding that can be reflected in either effective use or overt description of the knowledge in question. Cognition and metacognition have four components: the domain and reasoning levels are the object level and equate to cognition. The monitoring and reflection levels are the meta-level, and are what we mean in this thesis by metacognition.

Modulate - Move from one key to another.

M (Monitoring) level - At the M level evaluations and diagnoses about the lower level activities will take place.

Motif (or Motive) - The briefest intelligible and self-existent melodic or rhythmic unit. It may be of two notes or more.

Pitch - The phenomenon of varying pitch of sounds depends on variety vibration-frequency in the sounding body. A = 440 [vibrations per second] is now the standard British pitch.

R (Reasoning) level - will represent knowledge about the possible circumstances in which knowledge at the D level could be used. By this we mean that the R level represents knowledge of possible Compositional Methods.

Ref (Reflection) level - will examine the next three levels below it to decide if generalisation can be made.

Teaching Method - Teaching Method includes a Teaching Style and a Teaching Intervention.

Teaching Intervention - Is the form, content and justification of the intervention.

Teaching Style - A Teaching Style is a rule-based approach to teaching based on some psychological theory, e.g. cognitive apprenticeship or discovery learning.

Theme - Used in musical construction, this word generally means the same as 'subject', as that term is applied, for instance, in speaking of a piece in sonata or rondo form.

Transposition - The process of moving a melodic figure, section on composition up or down in semi-tones. The transposition mechanism that Symbolic Composer uses is essentially different from that of most sequencers because it separates the parameters of pitch from tonality. If a tonality is that of the C major scale, a transposition (in 'symbol-transpose' mode) of 1 will produce a diatonic transposition (D E F G A B C). However, 'symbol-transpose-chromatic' mode (which is what MetaMuse and Coleridge use) with the same transposition parameter of 1 will produce C# D# F F# G# A# C. Therefore transposition in this thesis is best thought of as 'chromatic' transposition.

Values - These cannot be achieved or abandoned like goals can. Values are persistent. In this thesis the agent value represented is pedagogical (concerned to be mentoring well, as defined by the analysis of human tutoring).

Wants - An attitude towards some proposition or world state (a goal). An agent may want to achieve all of its goals. Wants refer to a list of actions an agent might be willing to be committed to, commitment refers to the chosen way of achieving an action.

Appendix 1 - Small Survey of Music Experts

As we describe in Chapter 4 , in the second half of 1993 a small number of music cognition and education researchers were contacted by letter for help with this research project. Details of this thesis work was provided and a brief summary of our understanding of their work was given where appropriate. These experts were then asked the following:

> Have you, or has anyone you know of, followed up your study/work by examining in detail the meta-cognitive/reflective thinking of the following?
> - composers as they reflect on their work,
> - learners as they reflect on how they are being taught,
> - teachers as they reflect on how to teach composition

A summary of some of the response received are given in Table A1.1 (all replies were received October to December 1993). The purpose of providing this summary is to illustrate the fact that, in additional to bibliographical online searches, some effort was made to find up-to-date, detailed work regarding the reflective teaching and learning of musical composition. Furthermore, the replies in themselves are of interest. As Table A1.1 shows, the consensus from the experts was that the proposed area of work for this thesis had (in 1993) apparently not yet been done. In particular the reply from Professor Paynter (who was in a particularly reflective mood as he was about to retire from teaching and who was at the time co-editor of the British Journal of Music Education with Keith Swanwick) is very relevant to this study's aim of critical and creative mentoring pedagogical goals:

> "the most successful teachers <u>must</u> develop the skills of reflection and speculation in their pupils because composition is, by its nature, an analytical process."

In particular, the idea of 'reflection and speculation' is close to the idea of creative reflection being proposed in this thesis (i.e. speculation is similar to imagining opportunities).

Thus, the replies from these experts gave this project the impetus to go on to conduct a detailed, and an apparently new, study in this area (although of course the findings tell only a fraction of the story of metacognition in musical composition). Some of the replies are contentious and may give rise to debate within the music teaching community, particularly the opinions raised in Table A1.1 that composition teaching "seems to be a rare commodity in HE" and that "we tend towards a very 'hands-off' approach in this country". These opinions (and the lack of work found in searches of the literature) acted as motivation for work described in this thesis to provide a more scientific (and in-depth) account of how theories of teaching and cognition can be applied to musical composition learning in higher-education. However, as the literature review in Chapter 2 points out, there is no one correct approach to teaching musical composition, this thesis work explores only one approach.

Table A1.1
<u>Small survey of experts in the field of musical cognition and education research</u>

Expert	Institution of expert at time of reply	Brief extracts from replies
Roland Person on behalf of George Pratt	University of Huddersfield	"I have found that there are very few accounts of teacher-student interaction in composition teaching ... As far as I know, there is nothing at all discussing the teaching of composition at least not from a scientific point of view, and I don't think there is any research done on the introspective (and metacognitive) in composing. Any effort in that direction would be most welcome within the cognitive sciences of music."
Suzie O'Neill on behalf of John Sloboda	University of Keele	" ... although I have discussed it [the letter] with Professor John Sloboda, we both unfortunately have very little information on the reflective practices of either composers or teachers of composition."
John Paynter	University of York	"... you will know that this field [musical creativity], is a field I have worked in for close to 40 years. Everything that I have done has been towards helping children (and adults) to develop the 'capacity to reflect upon their experiences (of music's affective power) ... I do not accept that the Swanwick/Tillman "sequence" tells even half the story; but I know of no systematic study of the kind you mention." "I have to say that, having taught in the way I do for so many years ... I have no hesitation in saying that all the evidence points to (i) the development of reflection upon what is made by those who make it (ii) 'reflection' of the kind we have in mind is an essential part of the teaching process which cannot work otherwise (iii) the most successful teachers <u>must</u> develop the skills of reflection and speculation in their pupils because composition is, by its nature, an analytical process."
Peter Webster	Northwestern University	Provided six references with abstracts from his own database of such research.
David Hargreaves	University of Leicester	Provided references by Johnson-Laird (modelling jazz improvisation) and Kratus (for school children).
Keith Swanwick	Institute of Education	"The references you give in searching for the processes of meta-cognition are the only ones I would be able to offer myself. The area is very little explored." Professor Swanwick then gave some references to related work by aural musicians.
Peter Driver	Goldsmiths' College, University of London	"You identify an area which has worried me for a long time, particularly in Higher Education. Composition teaching seems to be a rare commodity in HE, where the process is often limited to subjective criticism of student work, without any adequate training in techniques."
Nigel Morgan	Independent educational consultant & composer	"Composition studies at undergraduate level are unlikely to prove very useful because we tend towards a very 'hands-off' approach in this country. This means we don't train composers as we train performers. I regard myself as fortunate in this respect as I studied abroad, and very formally."

Appendix 2 - Categories for Analysis

Tables A2.1 and A2.2 give a brief summary of the goals, sub-goal and utterance categories used in the interaction analysis. This summary is provided as a quick reference to assist understanding of the interaction analyses described in this thesis.

Table A2.1
Summary of goals and sub-goals

Goal/sub-goal	Brief definition
Creative thinking goal	Constrained to creative reflection: the ability of a learner to imagine opportunities in novel situations and to then make accurate predictions about these opportunities.
Creative imagine opportunity sub-goal	Interaction (verbal and/or musical and/or actions) by either teacher or learner that concerns the mental imaging of a creative idea in a novel context.
Creative make prediction sub-goal	Interaction by either (i) the teacher to elicit a prediction, or (ii) the learner that indicates that a prediction has been made about how an imagined novel opportunity will sound when played.
Creative accurate prediction sub-goal	Interaction by either teacher or learner that indicates that a successful prediction has been made about how an imagined novel opportunity will sound when played.
Metacognitive intervention goal	Has an implicit intention of adding a goal to the learner's head to help them monitor their own progress or to reflect.
target M or Ref sub-goal	Usually an open-ended question that involve the teacher's attempts to elicit verbal self-explanations from the learner about their own attempts at creative reflection. M = Monitoring, Ref = Reflection.
Metacognitive thinking goal	An understanding of knowledge (i.e. monitoring and reflection) that can be reflected in either effective use or overt description of the knowledge in question.
Monitoring evaluate sub-goal	Interaction that involves some evaluative comment about the match between a prediction and an outcome is indicative of monitoring.
Monitoring diagnose sub-goal	An attempt to diagnose why something did or did not work.
Reflect predict sub-goal	A pause (.9 seconds upwards) where the context shows that the learner reflects about a prediction before actually using a mentoring goal to make a prediction.
Reflect imagine opportunity sub-goal	Pauses (.9 seconds upwards), or utterances like 'umm', where the learner reflects about an opportunity before actually using an mentoring goal to state what that opportunity is.

Table A2.1 (continued)
Summary of goals and sub-goals

Goal/sub-goal	Brief definition
Critical thinking goal	Thinking that (1) facilitates judgement because it (2) relies on criteria, (3) is self-correcting, and (4) is sensitive to context. To paraphrase Lipman (1991) on critical thinking: 1. Where knowledge and experience are not merely possessed but applied to practice, we are likely to see clear examples of judgement. Good judgement takes everything relevant into account and are the products of skilfully performed acts. 2. Criteria are reasons; a particularly reliable kind. Criteria, and particularly standards, are among the most valuable instruments of rational procedure. 3. Insofar as each participant in the community of inquiry is able to internalise the methodology of the community (where members begin looking for and correcting each other's methods and procedures) as a whole, each is able to become self-correcting in his or her own thinking. 4. Thinking that is sensitive to context involves recognition of exceptional or irregular circumstances (the character of a witness in a trail may govern our view of a statements truth); special limitations, contingencies, or constraints; and overall configuration (remarks taken out of a statement and used elsewhere may change context).
Critical judgement sub-goal	Reaching a conclusion about a complex situation or phenomenon, generally without algorithmic deduction or calculation.
Critical probing sub-goal	Probing can be a focused used of observations of a student's phrase. Probing provides guidance on how to structure new knowledge.
Critical challenging sub-goal	This is adversarial in that a proposition, for example, may not be accepted as true without further evidence being provided.
Critical clarification sub-goal	Further elaboration of some point may be requested or given because (i) a previous attempt was unclear or (ii) a response was required.
Critical give reasons sub-goal	Any interaction that involves the giving of criteria as a reason.
Critical give evidence sub-goal	Similar to a court of law, if some claim or judgement is made then evidence to back up a the claim or judgement may be requested.
Motivation goal	The sense of a willingness to pursue activities.
Motivation intrinsic sub-goal	This usually involves the teaching agent giving an account of its approach to composition. Such a description would be intended to motivate the learner to develop their own approach to composition, perhaps on similar lines.
Motivation extrinsic sub-goal	Providing a concrete reason for pursuing a task.
Motivation encouragement sub-goal	Utterances like repeating another agent's utterance, or "Right" are viewed here as often having the intention of giving positive feedback.
Task goal	This is a description of what the teaching and learning interactions will aim to achieve, it provides a statement against which learning outcomes can be measured.

Table A2.2
Summary of acts and relations

Act	Brief definition
Communicative Acts (a main term)	Used to realise, with different contents, many of the upper level KMf intermediate and pedagogical goals.
assertion	Communicates that the speaker believes/accepts the content to be a fact.
assertion confirmation	A earlier assertion by another speaker has been accepted by the current speaker.
question	There are different types of question. A wh-question communicates that speaker wants hearer to provide certain information, more or less specific, and that speaker believes hearer can provide that information.
request	Like questions, except concerned with action, getting other to do something, with exception of information providing which would make it a question: speaker wants hearer to perform action A, speaker believes hearer can perform action A. Or announcing that something needs to be done and then doing it.
offer & accept	A suggestion of how to proceed, 'who should do what next'. If the teachers accepts the learner's offer, or if the student accepts the teacher's, then the teacher and learner set about getting 'to work'. If an offer is spread over a number of turns then code as 'offer continue'. If confirming a previously accepted offer code as 'accept confirm'.
reject	An offer is not taken up, or an assertion is not accepted.
transform	Where an offer is changed in some way based on negotiation but remains similar to the original offer. Here, "transform" means a communicative act has been made, e.g. an offer, and it (transform) bears a special *relation* to a previous one of the other speaker to the extent that the contents of the current offer "transforms" that of the previous.
complete	This is where, for example, the teacher or student leaves a sufficiently long gap (>= .7 seconds) for the other to add the correction or continuation to the end of a sentence. Here, "complete" means a communicative act has been made, e.g. an assertion, and it bears a special *relation* to a previous one of the other speaker to the extent that the content of the current assertion "completes" that of the previous act (e.g. an offer).
action	Non-linguistic forms of communication (e.g. musical actions that have communicative intent or pointing at the computer screen).

Note: complete and transform (relationships between acts) are not discussed in the main body of the thesis but are explored in Appendix 4, Section 4.

Appendix 3 - Additional Details of the Empirical Study

What follows are additional details of the planning for the study described in Chapter 5 of this thesis.

1. Introduction

The study took place at Liverpool Hope University College on Tuesday November 5, 1996. The aims of the formative study were:

- to gather data to answer the following research question: what are the interactive means by which a music composition teacher stimulates creative problem-seeking and creative reflection?
- more specifically, to ascertain how a teacher initiates and adapts plans in a process of mentoring about the transposition of a motif.
- to provide some empirical data on the use of the categories outlined in the scheme described in Chapter 3 (and detailed in Appendix 2).

2. Instructions given to the teacher

The following instructions were given to the teacher in advance of the session:

Please interact with the students for 30 minutes and try to promote the learning outcome of creative reflection by using a process of mentoring. Use the task described below and Coleridge as the basis for interaction with the students. For clarification purposes, the terms used in this statement are defined below:

- *Mentoring* means that you as a teacher should intends to foster the goal of *creative reflection* in the learner by a process of promoting mentoring goals in your interactions with the learner.
- *Creative reflection* is defined as the ability of a learner to imagine opportunities in novel situations and to then make accurate predictions about these opportunities. For example, assume a learner has just been told that chromatic transposition of a motif (e.g. sequentially by small interval values) produces a phrase with a trajectory. If that learner is then asked to suggest a series of intervals for the transpositions, to then make a prediction about how it will 'sound', and if this prediction matches the phrase when it is played then we have an example of creative reflection in a learning situation. Success at creative reflection, i.e. the ability to make accurate predictions and imagine opportunities, can therefore be gauged by achieving a match between a learner prediction (e.g. a description of what will happen if a series of transpositions are applied to a motif) and the outcome of actually applying some novel transformation (e.g. how the phrase sounds when it is played).
- Mentoring intends to support the co-construction of knowledge and motivation to learn, to provide challenge through critical thinking and vision through creative thinking. The exact meaning of these four interaction goals are left for your own interpretation. However, it is important to add that the interactions should assist the learner in the process of *problem-seeking*, i.e. finding out for themselves how the elaboration of a given motif can assist in the formulation of a compositional idea.

If you have any prior knowledge of a student this should summarised and given to the observer in advance of the session. The teacher is requested to conduct all 'get to know the student' type interactions in the formal session. This is because the observer is watching for the use of this knowledge (about a learner) in planning and interaction.

Furthermore, on the day of the session the teacher asked by Cook if there was any instructions Cook would like to add. Cook replied that he should not be afraid of leaving silent gaps at appropriate places for the student to reflect.

3. Information sheet for students

The following information sheet was given to the student in advance of the session

Reflective Learning in Music Composition

'I get up early, and as soon as I have dressed I go down on my knees and pray God and the Blessed Virgin that I may have another successful day. Then when I have had breakfast I sit down at the clavier and begin my search. If I hit on an idea quickly, it goes ahead easily and without much trouble. But if I can't get on, I know I must have forfeited God's grace by some fault and then I pray for more grace till I'm forgiven.'

For most composers the act of composition still continues to be the daily 'search' for ideas that it was for Joseph Haydn. And, in essence, the nature of that 'search' has probably changed little in 200 years. Patient reflection and deliberation that all composers crave continue to face up to the pressure of the deadline, and most particularly now in a student's earliest experience, of the composing activity - in the music classroom where it is considered a vital element in music education.

Such is this pressure to produce the next composition that we rarely give thought or time to deliberating on the nature and effectiveness of our thinking process. We slide into a way of working and often retain a method of 'getting things done' that can remain in place for years.

Despite the importance of composition to music education composers are rarely taught. They usually learn: from example, by analogy, by discovery and from their own failures. Instruction is rare, and 'method' frowned upon except as a last resort to produce an outcome. By composing we learn, but we rarely reflect about how we learn and even less about the nature and mode of our process of thinking.

Developments across the disciplines of computer science, artificial intelligence and education are seeking pathways to Intelligent Learning Environments which have the power, 'intelligence' and flexibility to contribute new learning styles and opportunities for aiding creativity. Music composition presents a particularly fascinating problem to researchers as the activity of composing tends towards the seeking and creating of problems before attempting to solve them in any way. There is also very little known about how composers think when they are actually composing.

Before such Intelligent Learning Environments can be modelled and built we have to explore practice in composition teaching: what is appropriate teaching? How and when should a teacher intervene in a student's deliberations on, or execution of, their composition? And, most important, what should be the form, content and justification for that intervention?

A good teacher does not elicit information or direction directly but questions the student in order to tease out answers or solutions from the student. The student is encouraged to think, consider, postulate, assess, appraise, examine, experiment and so on. Teaching interventions are all about finding the right question to ask at the right time.

The next step for the researcher is to monitor the effect a teaching intervention has on the student. Does the intervention simply produce an answer or solution or go beyond that to encourage the student to think and reflect more effectively for themselves? Using information gained from these and other questions the researcher begins to be able to build a picture of teacher-learner interaction. This may ultimately provide the foundation for an Intelligent Learning Environment that is able to reflect about the way it teaches.

Whatever the outcomes of such research for the computer scientist, AI specialist or educator the composer has only to benefit. The introduction of highly interactive computer applications for composition has tended to focus the composing activity more continuously on creating a succession of notes and sounds rather than encouraging the composer to reflect, plan, scheme or design. Improvisation rules, and composing becomes a chain of small-scale feedback loops . . . The outcome of this practice is that composers find that they can only think when inside this technology-induced feedback loop. Reflective thought becomes disabled when it has the potential for being with the composer constantly. Haydn may have needed to 'search' at the clavier but it's highly unlikely that he stopped thinking and reflecting about his music as he shut the door on his music room for the day.

John Cook - School of Technology and Information Studies, Thames Valley University.

Nigel Morgan - Liverpool Hope University.

4. Task Design

The task was to ask the learner to generate, by transposition a 4 note pattern, a musical phrase. Slonimsky pattern No 1 (i.e. c5 c#5 f#5 g5) was given at first. The initial teaching plan was known by the teacher-composer and observer in advance. The overall tutorial task goal was 'reflecting on the inner structure of a musical pattern'. There were three task sub-goals associated with the overall tutorial task goal: to extrapolate an example of structural content from the Learning Agent's phrase, second to critically analyse the extrapolation, and finally that of placing this extrapolation in the context of a whole phrase.

5. Observer guidelines and questions for interview

5.1 Observer guidelines

Because the first aim of the session was to investigate the interactive means by which a music composition teacher stimulates creative problem-seeking and creative reflection, in the post-experimental interviews the teacher and learners will be given cues gathered by an observer of the session. Post-experimental cues (Ericsson and Simon, 1993, p. xvi, see Chapter 4 for a discussion), act as an to aid recall of thought episodes at specific points and will attempt to focus on issues of intentions, plans, dialogue goals and plan revision. The observer of the sessions (Cook) was particularly watching out for the following events to act as post-experimental cues:

- Incidents where the intention works, e.g. it appears to foster creative reflection.
- Occasions where the intention fails, e.g. a learner declines to accept the tutorial task goal.
- Incidents where a plan appears to have been changed on the basis of some knowledge about the learner.
- Times when a new dialogue goal appears to have been introduced. In the subsequent interview the observer will attempt to ascertain from the teacher-composer the extent of plan revision.
- Changes in planning etc. that seem to have evolved over the 3 task-then-interview sessions (has the teacher made any reflective generalisations?).

5.2 Rationale for the questions to learner and teacher

We were on the look out for answers to the above research question (Section 1 of this appendix) and aspects of creative reflection (as defined above). We used questions 1-4 below as guides for post experimental cues. Question 5 tries to check how much the experimental setting affected the subject. Question 6 attempts to find out what values, motivations and beliefs, etc., the learner/teacher holds about their own about learning/teaching (this question produced some useful answers in the pilot study and was hence kept for this study). At the end of the interview both students and teacher were to be asked for their attitudes regarding the use of Coleridge (question 7).

5.3 Questions for interview

1. Why did you make this particular *(response/teaching intervention)?* (Based on our observations in the session.) What were you thinking when you made that particular *(response/teaching intervention)* ? What was your major concern?
2. How did you evaluate *(your/the student's)* response to the teaching intervention?
3. Do you think you would make the same *(response/teaching intervention)* again in the future? If you were to change some of your approach to *(learning/teaching)* would this have a positive or negative outcome?
4. Why did you decide to change your *(learning/teaching)* approach at this particular point? (Based on our observations in the session.)
5. In what way were your thoughts and *(learning/teaching)* methods different in this experiment from your thoughts and methods when you work with a *(teacher/student)* on your own?

6. Do you think your *(learning/teaching)* has changed in any way over the last year or two?
7. (For TA) Do you think the learning environment (Coleridge) has potential for use in teaching with other students?

Additional comments were recorded.

NB. It was originally intended to asked question 7 to the learners, however this was omitted with learner G, therefore the other student's responses have not been transcribed.

6. Conclusion

On the basis of the answers by subjects to question 5 we can assert that the teacher and three of the learners did not seem to feel that the observation setting had an undue influence on them. Learner 2 did feel that the observation setting had an undue influence on him. On the whole we conclude that there is suggestive evidence to support the view that the data gathered was a reliable record of teacher-learner interactions. The students normally get composition tuition on a one-to-one basis and the sessions observed will not have been too unusual for them, a conclusion that most of the above comments appear to support. However, this must be weighed against the knowledge that being observed will tend to exert some change of behaviour on the object of observation.

Appendix 4 - First Analysis, Related Additional Results

1. Goals, sub-goals and communicative acts

On the basis of further empirical analyses using the Chapter 5 result of category scores (i.e. Tables 5.2 and 5.3), it is possible to draw separate goal trees for each agent and say how often the Interactive level sub-goals and act-actions were used. Scores for the Intermediate Level shown in Figures A4.1 and A4.2 were calculated by expressing the total count for that goal, as a percentage of the total goal count, in the study, for that agent. For example, the score for 'creative imagine opportunity' for the learner = 26*100/198 = 13.13%. The scores for the act-action level shows the total number of times that act-actions were used to satisfy the interactive level sub-goal further up the goal tree. Note that the total score for acts at the utterance level (for a particular sub-goal) can vary from the score for that related sub-goal higher up the tree (i.e. the sub-goal score given in Table 5.2); this is because the utterance level includes actions and because one occurrence of a sub-goal could mean the use of several communicative acts. The scores shown in the following Figures (A4.1 and A4.2) relate to the agent turn when a goal was first introduced in an interaction, and excludes subsequent turns when the agent may have continued to try and satisfy a goal by using further acts or actions. (See Appendix 2 for a summary of the goal and act categories used in the interaction analyses.) Note that one or more different acts-actions may have been used in an agent turn to introduce a goal, and that this feature is captured in the act-action scores shown in the goal trees.

The basic structure of the learner goal trees and acts-actions used to achieve them are shown in Figure A4.1 (which is actually a set of partial hierarchies in that no link is specified for joining the different goal trees shown in Figure A4.1; percentages of >=10% are shown in bold).

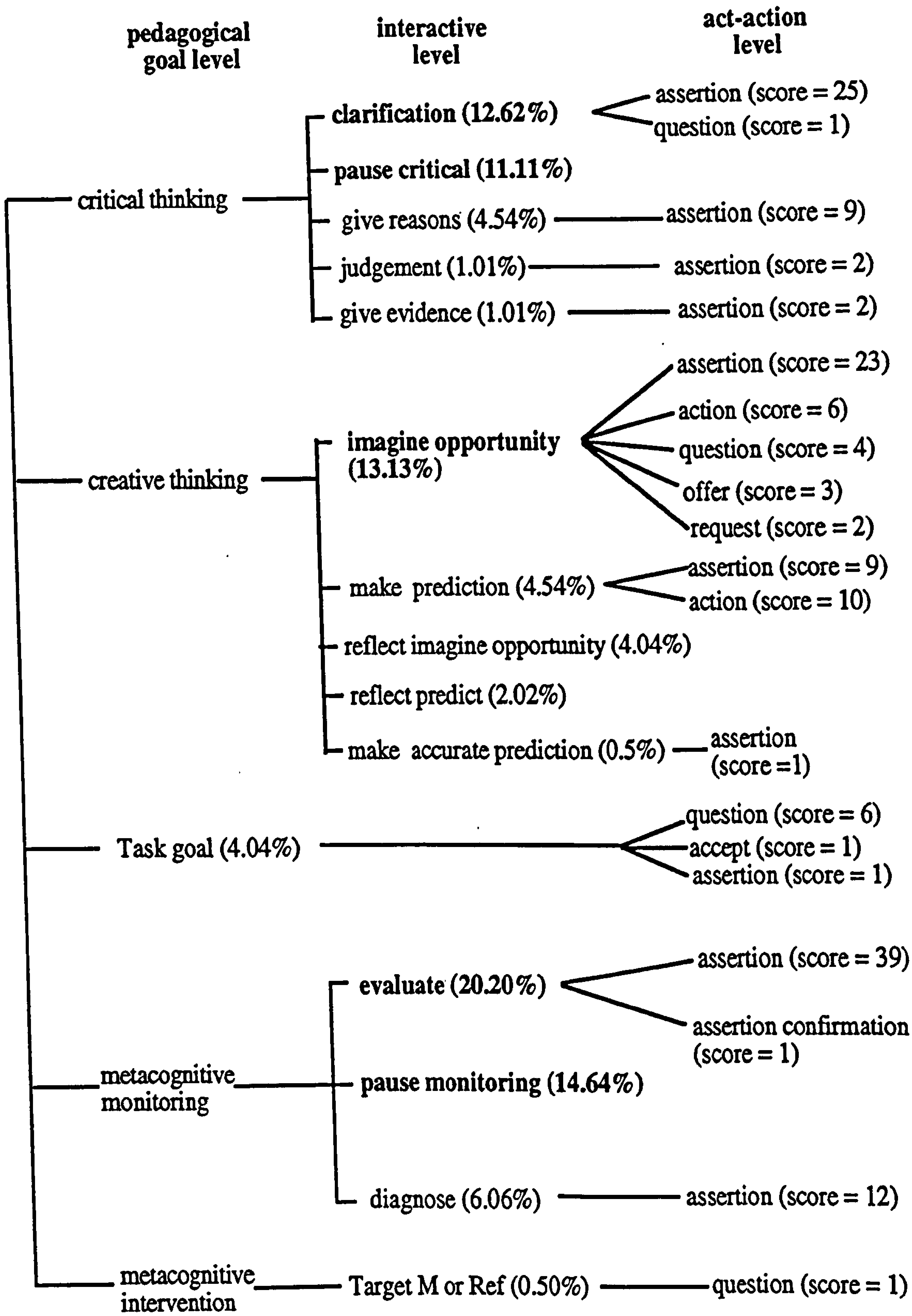

Figure A4.1. Partial goal trees for learner (% of >=10% are shown in bold).

The basic structure of the teacher goal tree and acts used to achieve them are shown in Figure A4.2 part 1 and 2 (like the learner tree, these are partial goal-act hierarchies; percentage goal use of >=10% are shown in bold).

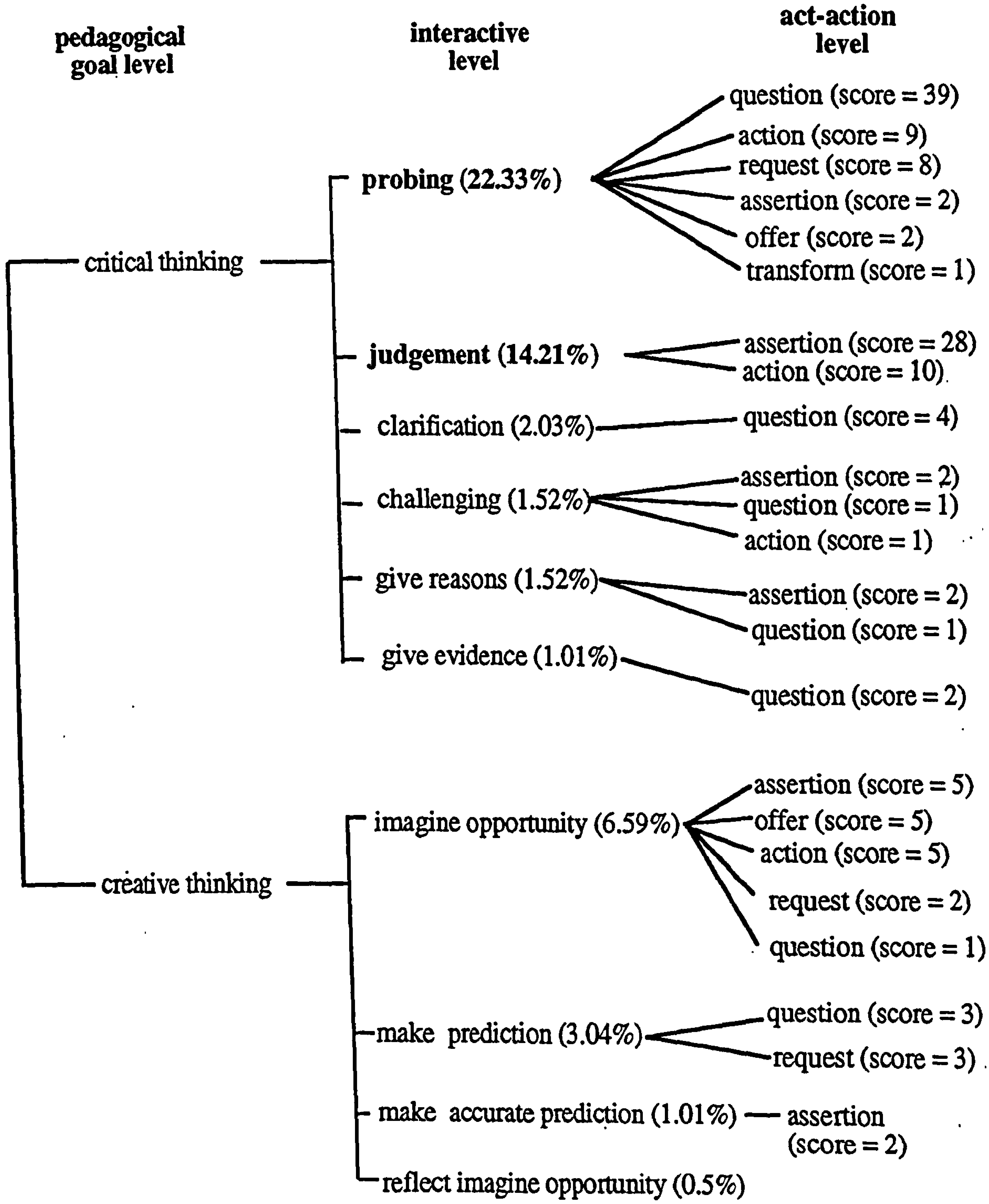

Figure A4.2 (part 1). Partial goal trees for teacher
(% of >=10% are shown in bold).

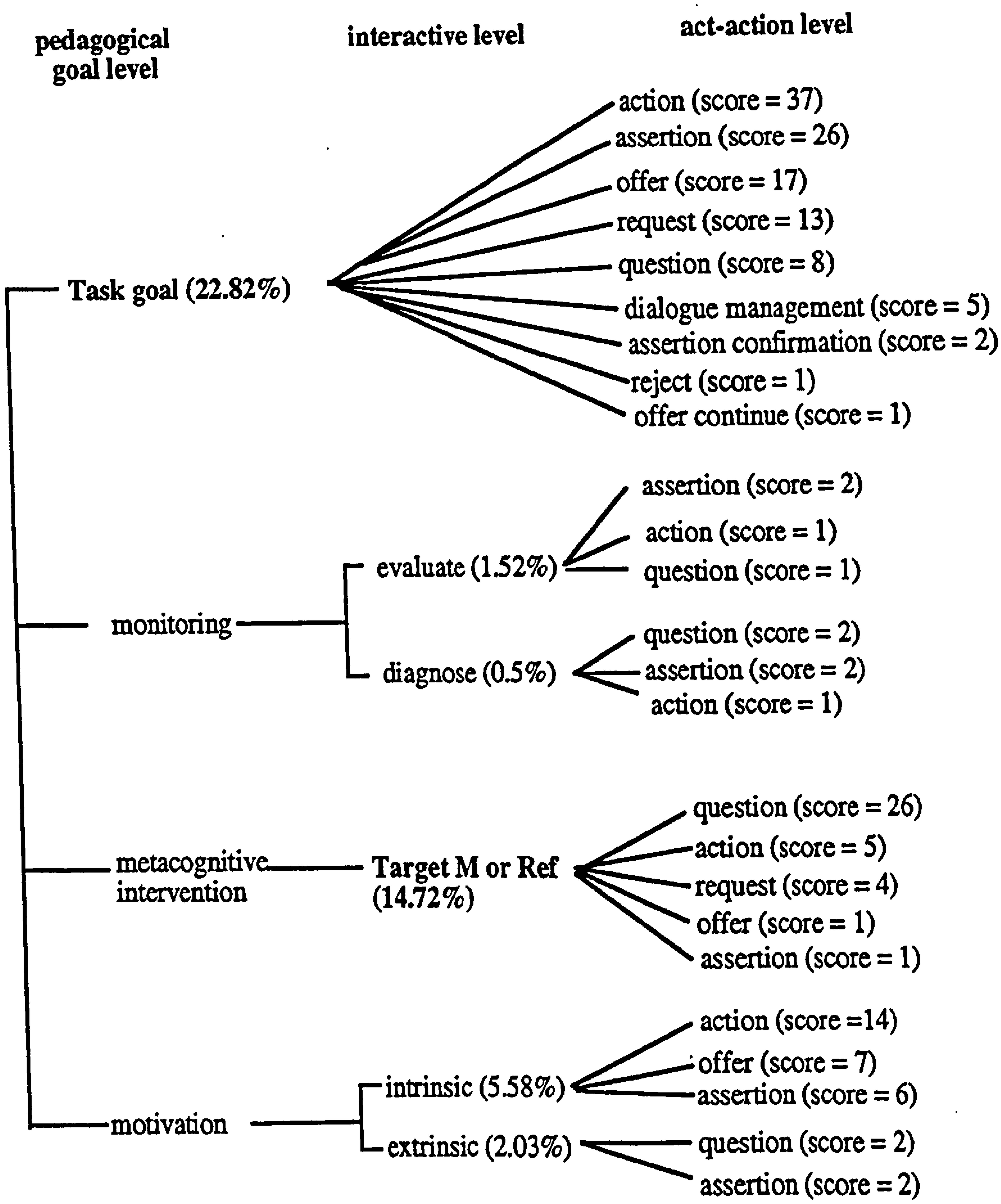

Figure A4.2 (part 2). Partial goal trees for teacher
(% of >=10% are shown in bold).

2. Motivation

Figure A4.3 shows that 'motivation encouragement' was used by the teacher in the empirical study on 70 occasions.

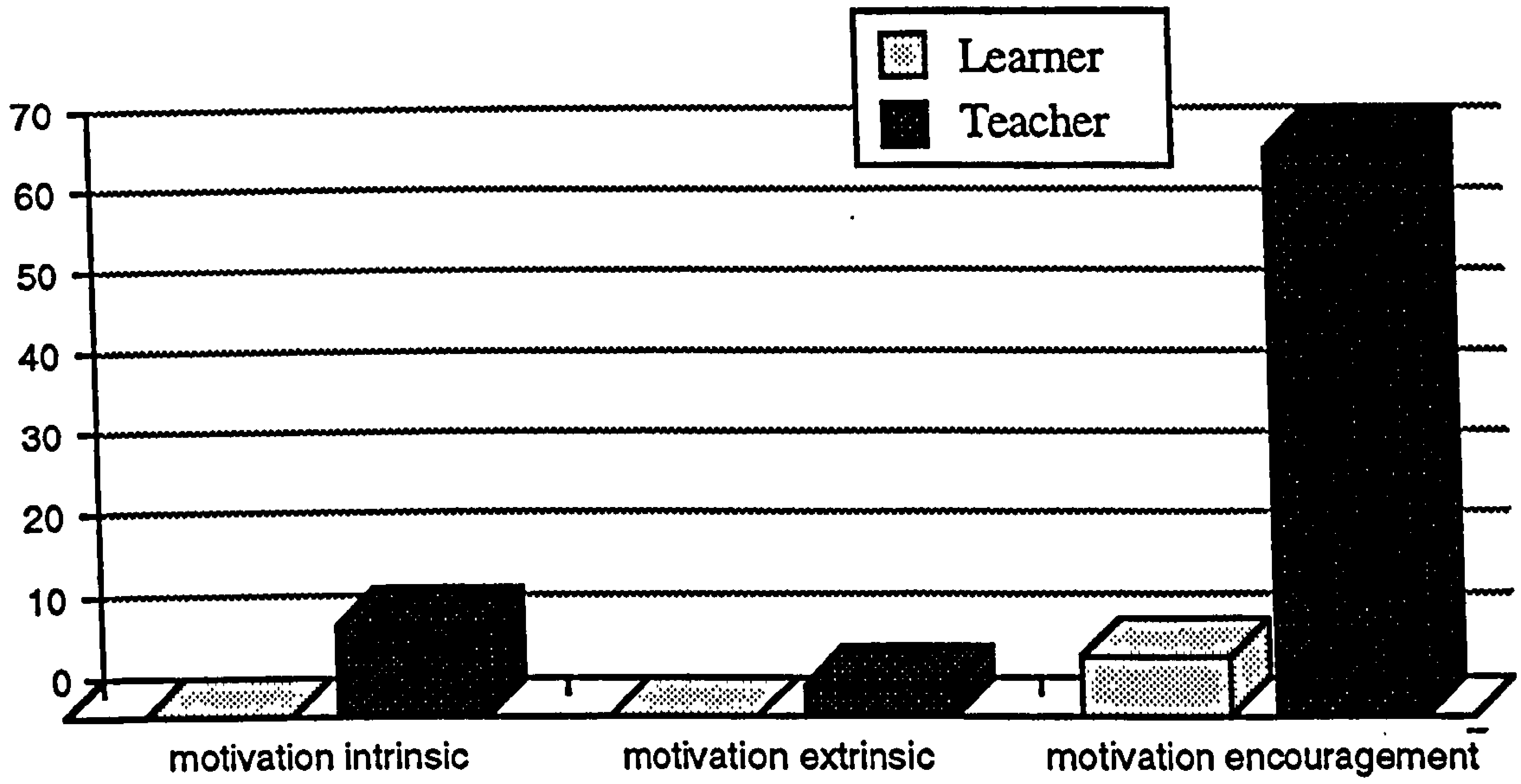

Figure A4.3. Motivation goal scores.

Its main function seemed to be to keep the interactions flowing smoothly and to keep the learner talking (giving the self-explanations). Motivation encouragements were usually encoded with an associated communicative act (almost always either an assertion, assertion confirmation, or dialogue management). Interestingly, the learners used motivation encouragement seven times. These were exclusively utterances like "Uh huh" (score = 5), "Yeah" (score = 1) and "Umm" (score = 1). They were used by the learner as cues to the tutor to keep talking.

Motivation encouragement is an example of what Bunt (1989, p. 52) calls "dialogue control acts". In his study of information dialogues conducted over computer terminal, Bunt found that 50% of the utterances were communicative actions that served to make the dialogue proceed smoothly and stay on the right tracks. Dialogue management in this study was achieved by 'motivation encouragement' (score = 77) and 'assertion confirmation' (score = 292). 52 out of the 77 'motivation encouragement' in this study had the act 'assertion confirmation' associated with it. 'Accept confirm' (score =23) also performed a dialogue management function. Therefore, the total number of dialogue management utterances in this study = 77 + (292 - 52) + 23 = 340.

If we express the total number of occurrences of dialogue management acts in this study (score = 340) as a percentage of all communicative act occurrences in Table 5.3 (i.e. the total for communicative acts (score = 1259) plus relations (score = 20) plus dialogue management (score = 43), total = 1322) then we get a result that dialogue management (control) in this study accounted for only 25.7% as the total score for dialogue management acts in this study. Of course the Bunt study may have categorised the dialogue control acts in different ways and the domain was different to the this study. However, 24.3% seems like a large discrepancy (between Bunt's result and this study's). One possible explanation could be that information dialogues like Bunt's are very different from mentoring interactions.

'Motivation intrinsic' (the teacher score = 11) usually involved the teaching agent giving an account of his approach to composition. Such a description would be intended to motivate the learner to develop their own approach to composition, perhaps on similar lines, but certainly one that motivates them to work. 'Extrinsic motivation' (the teacher score = 4) involved the teacher giving a learner a concrete reason for completing a task.

Although the scores for intrinsic and extrinsic motivation are relatively low, their presence can be a key to promoting learning. In Chapter 2 it was pointed out that a composer needs a well developed memory and the ability to visualise and make predictions about the structure of a planned composition if they are to compose successfully (e.g. to develop themes over for long piece). This would seem to suggest the need for the practising of 'creative reflection' in a learning situation. But the required practice will not take place if the learner is not motivated to do this. In session 4 the following utterance by the teacher was coded as intrinsic motivation:

> But I, as I'm going to show you later on, umm, I've actually used that motif in a number of compositions, I going to show you an example of the study I've written.

The teacher seemed to saying, 'OK we are working on a small pattern here, but I've used it for the basis of a full composition, this is all worth the effort, it is one way of developing your compositional abilities', etc.

An interesting line of future research to pursue has been outlined by Del Soldato (1994). Del Soldato describes an instructional planner able to make decisions (about the next task to do) in order to achieve the goals of traversing the domain knowledge relating to Prolog debugging and maintaining the learner's optimal motivational state.

3. Communicative acts

Figure A4.4 shows that the most often used communicative act was assertion (total score = 480). Of course, this quantitative fact is of little use unless the context for the use of acts is known. The tables used in analysis four (i.e. the tables given in Appendix 6 that incorporate into the analysis post-experimental cue data) give a good indication of how acts are used to achieve goals in various extended interactions. The fifth analysis tried to identify the acts used to achieve the task goal (see Section 1 of Appendix 8). One point that Figure A4.4 illustrates very well, however, is that conflict was not a major element of the sessions observed, the reject scores for the learner and the teacher.were low ('reject' scores were 3 and 5 respectively). It is worth reiterating the point made in Chapters 3 and 4, i.e. that the analysis only coded what are being termed 'primary acts' (assertion, question, request, offer, accept and reject). The other categories shown on Figure A4.4 are more specific forms of a primary act, e.g. 'assertion confirmation' is a dialogue related to assertion, and usually involved an 'assertion' by a speaker, followed by a repeat of this assertion in the form of an 'assertion confirmation' by the hearer (i.e. dialogue management). This differs to the rich set of communicative actions proposed by others, e.g. Bunt (1989).

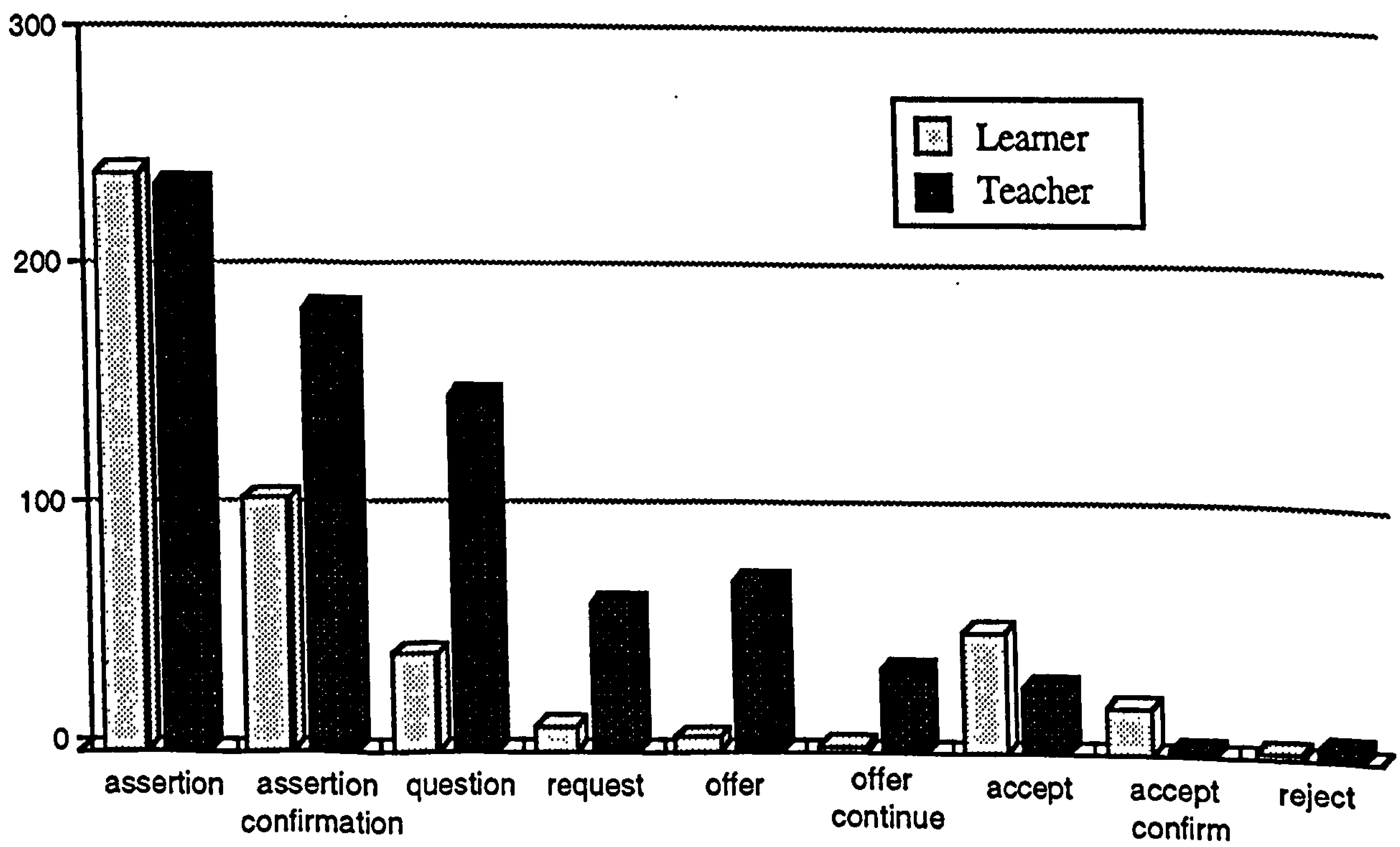

Figure A4.4. Communicative act scores.

4. Relationships between acts

'Complete' is where, for example, the teacher or student leaves a sufficiently long pause (>= .7 seconds) for the other to add the correction or continuation to the end of a sentence. Here, "complete" means a communicative act has been made, e.g. an assertion, and it bears a special relation to a previous one of the other speaker to the extent that the content of the current assertion "completes" that of the previous act (e.g. an offer). A pause does not always need to be left. Figure A4.5 shows that 11 occurrences of learner 'complete' were identified in the interactions.

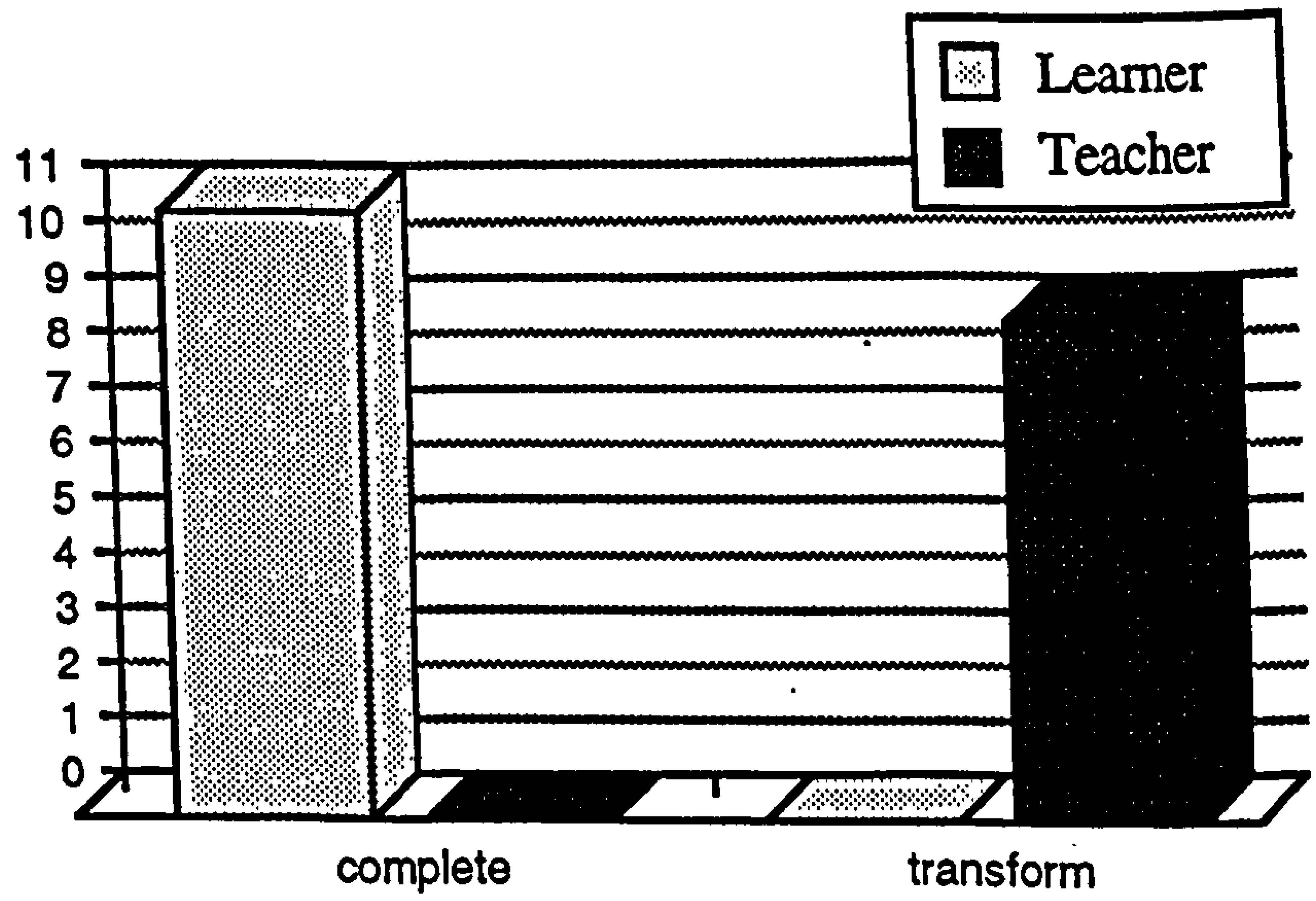

Figure A4.5. *Relations between acts.*

The second type of relationship between acts is 'transform', which occurs where an 'offer' is changed in some way based on negotiation or knowledge of the learner, but remains similar to the original 'offer'. Here, "transform" means a communicative act has been made, e.g. an 'offer', and it ('transform') bears a special relation the previous act (of another speaker or the same speaker) to the extent that the contents of the current act "transforms" that of the previous. Figure A4.5 shows that there were 9 occurrences of teacher 'transform' identified in the analysis. Table A4.1 gives an example of 'transform' from session one of the empirical study. Utterance TA2 shows the act 'transform', which has a relationship to the second question posed at TA1, by the same speaker, about the large leaps segmenting the music. At TA2 the learner is being asked to imagine playing the phrase on the fiddle (which is the learner's instrument) so that they might be able to better visualise the purpose of the large interval "jumps". Interestingly, the device of getting the learner to imagine they are playing their instrument was also used as part of another two instances of 'transform' by the mentor. In session 2, this transform device was used by the mentor whilst referring to an example of the learner's own instrument: "In fact this would, you could almost play this on the clarinet" and in session 3 in the context of introducing the task "for, let's say, for let's say for piano, your a pianist aren't you?". On each occasion the mentor made use of his knowledge of what instrument the learner plays to 'transform' an act into something that has more meaning to the learner. Essentially, the mentor would modify an act on the basis of prior knowledge that the mentor had of the student.

Table A4.1
Example of 'transform' from session 1

TA = Teaching Agent, LA = Learning Agent

Agent-utterance	goal	act	other	commentary
TA1: =Yeah. It might, these, these [USES T BAR TO POINT TO 28 AND 24] surprises that you you mentioned, very large leaps. Umm. Do they, segment the music?	critical probing	ass-conf. question	action	Comment: They have just heard the phrase played back and the teacher is asking the learner if the two large leaps segment the music. The mentor is providing some context for the question, this type of communicative act is not, however, recorded in the Knowledge Mentoring analysis scheme (only primary acts are recorded).
Or do you, do you see that jump there		question		
[POINTS WITH FINGER TO 28] triggering this little phrase here?			action	
[PULLS CURSOR OVER 2 2 1]			action	
TA2: I mean, if you were, if you were playing this on a fiddle, where would you put the, and you were, and you were bowing it, you were using the legato bows you were playing several phrases in, in each	critical probing	transform		Comment: This act is transforming the question posed above about the large leaps segmenting the music. The learner is being asked to imagine playing the phrase on the fiddle (which is the learner's instrument) so that they might be able to better visualise the large leaps.
bow. How would you bow it?		question		
TA3: (1.8) Where would you put the phrasement bars?	above goal still active	question	pause-critical	Comment: the above transformation (TA2) is rounded off with a reminder that when playing the fiddle you would have to play in phrases, which is to a certain extent similar to the segmentation of the music.
LA4: (4.82) Well there would, yeah, there would, there wou:ld be a segmentation there [POINTS WITH FINGER TO 28]=	critical clarification	assertion	pause-critical	Comment: after a pause for thought the learner gives some clarification on the segmentation of the music.

A critique of the KMf categorisation scheme becomes apparent in Table A4.1 at TA1. In other schemes, e.g. Labov and Fanshel's (1977) Discourse Analysis, the two questions would be different types of question or possibly three questions. The first question:

> It might, these, these [USES T BAR TO POINT TO 28 AND 24] surprises that you you mentioned // very large leaps. Umm.

would be a context providing question. The second question:

> Do they, segment the music? Or do you, do you see that jump there [POINTS WITH FINGER TO 28] triggering this little phrase here? [PULLS CURSOR OVER 2 2 1]

could be two questions:

Question 1: Do they, segment the music?
Question 2: Or do you, do you see that jump there [POINTS WITH FINGER TO 28] triggering this little phrase here?

This example exemplifies the 'primary acts' approach taken in the KMf analysis (see Chapter 4 for a discussion).

5. 'Other' categories

Figure A4.6 shows four of the 'other' categories. Actions are discussed in Section 5.4.1. Table A4.2 gives a good example of the intensive use of musical acts. At TA1 the teacher overlaps his own talk (indicated by '//') with a musical example of what he thinks will be 'logical'. The learner is involved in an interaction about the example and immediately responds at LA3 by implying that the choice is a personal decision. At TA4 the teacher uses two interleaved musical examples (in square brackets) and one overlap (TA5) musical examples to illustrate what he is saying.

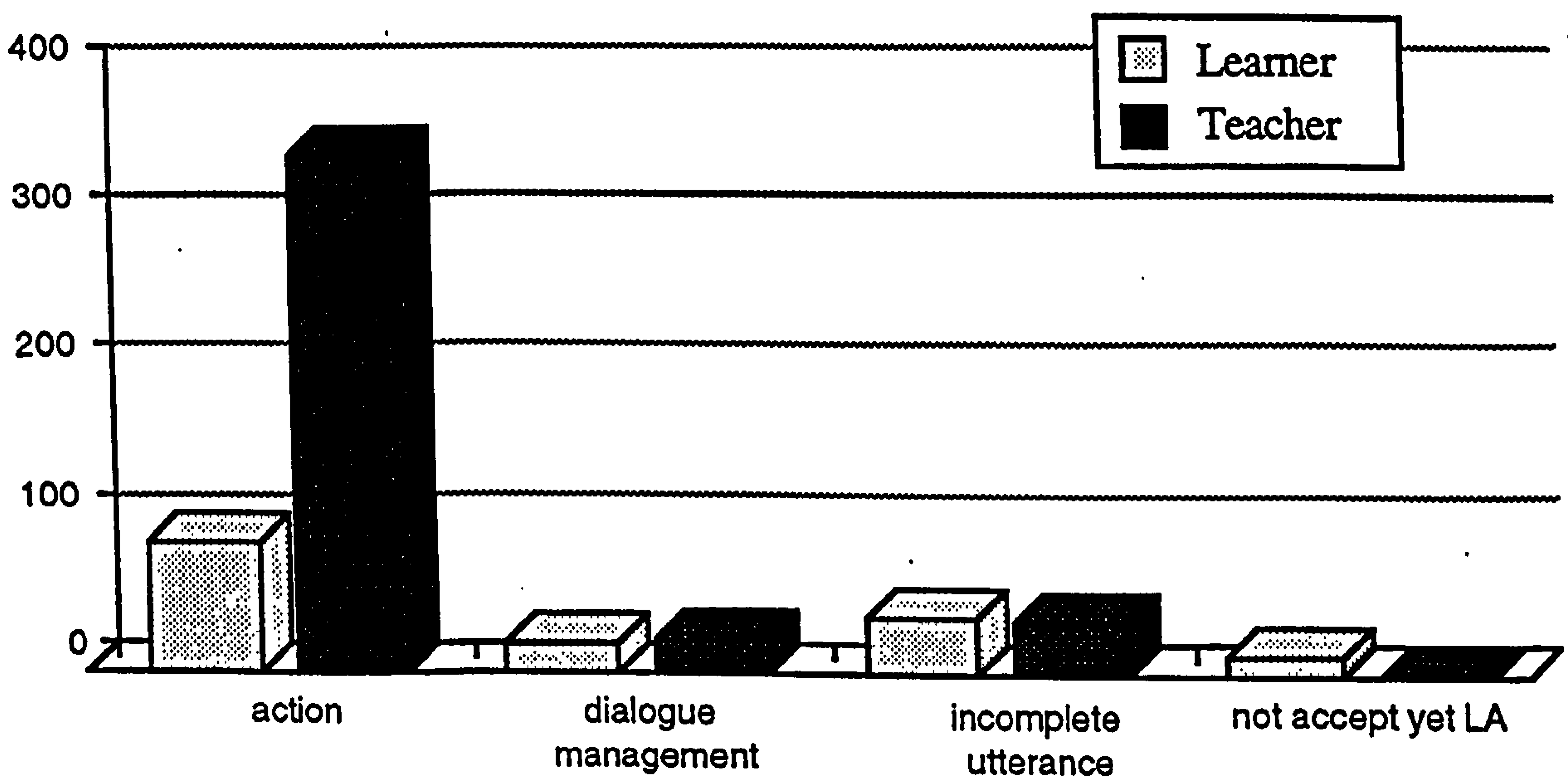

Figure A4.6. Other category scores.

Table A4.2
Example of musical acts from session 1

TA1: Do you see, so it would in fact be // very logical, in some respects=
TA2: [PLAYS NOTES C C# F# G]
LA3: =Yeah, but whether it's what you want.
TA4: Because you've just had [PLAYS OCTAVE ABOVE PLAYS MIDDLE, NOTES C C# C F# G AND C C# F# G] and your going to go to end [PLAYS LOWER DOWN F# G C C#] to end. So // in fact it's playing the same set of notes.
TA5: [PLAYS LOWER F# G C C# AS A CHORD]
LA6: Uhh huh=

The playing of examples is something that any computer-based mentoring agent would need to take into account, and indeed it is something that computers are good at. Of course, deciding when to play examples is more problematic and is perhaps something that the analyses conducted in this thesis has not adequately dealt with. An interesting line of research would be to use a different teachers on the same task to see if they were as active as the teacher used in this study and to develop a taxonomy of the best place in the interactions to make a musical act.

'Dialogue management' are utterances by either agent that seem aimed at keeping the interaction flowing smoothly. Typically they are nods of the head and an associated "uh huh" uttered whilst another agent is active (talking or playing). As a communicative act 'dialogue management' was often associated with the goal motivation encouragement (on some occasions it was also associated with accept). In retrospect 'dialogue management' seems like an obvious omission from the analysis categories (it was added in this 'other' category once the analysis got under way and its need became apparent). At around 21 occurrences for each agent over the four sessions, 'dialogue management' deserves to be included as an act in future versions of the analysis categories. However, as Bunt (1989, p. 70) has pointed out (see the related discussion in Chapter 4), dialogue management acts may not have the same status as other acts like question in that they are soon forgotten.

As the name suggests, incomplete utterances occurred when an agent, either through choice or interruption, failed to complete an utterance. At about 36 for each agent these had a fairly high occurrence. More analysis would be required to draw any conclusion about their significance, this would be a good line for future work, particularly from the perspective of comparing different teachers and learners. 'Not accept yet' (score = 13) all occurred in session 4 and was discussed in Section 5.4.3.

6. Pause Taxonomy

This result is discussed in Section 5.4.2. Additional results are given below.

Table A4.3
Average pause length by session

session score	reflect imag. opportunity	reflect predict	pause critical	pause monitoring	total
student 1	8.37	1.33	2.59	2.96	3.81
student 2	0.00	0.00	2.67	3.97	1.66
student 3	1.45	7.30	3.19	5.11	4.26
student 4	1.30	0.00	1.90	2.35	1.39
Total	2.78	2.16	2.59	3.60	

* note that on 4 occasions of different pause types, there was no silences. These pauses had an 'emm' or 'err', and were allocated 0.7 seconds.

Table A4.3 shows the mean average pause length for each student. The teacher's assessment (see Section 5.4.2) of some of the learners is not matched by the total average pause scores in Table A4.3. Interestingly, student 3 now has the highest average score for all four pause types (score = 4.26) and when it comes to her average for reflect predict she is well in front of the others with 7.30 seconds (remember that student 3 was the only student to make an accurate prediction). Furthermore, student 3 achieves the highest average score for pause monitoring (score = 5.11, which is related to monitoring by the learner); this may support the claim made elsewhere in this thesis that monitoring is the first step towards making accurate predictions. However, student 1 retains the top individual pause average of 8.37 seconds for reflect imagine opportunity. The fact that the weakest student (according to the teacher) has two scores of zero may also be an indictor that student 2 needs to build up or practice his mental modelling abilities. Finally, the total average pause lengths for the first three pause types is fairly close, being within a range of .62 tenths of a second of each other.

Appendix 5 -Third Analysis Detail

1. Detail of third analysis approach

The third analysis of data examined teacher's intervention to ascertain which learner interaction goal or communicative act preceded it. Such an analysis would, it was hoped, throw light on the research question: what are the interactive means by which a music composition teacher stimulates creative reflection? In particular, this analysis should give answers to the related question: 'Given a particular student intervention, what are the common forms of teacher response?' Because the aim of the analysis was to inform the design of a computer-based teaching agent, teacher interventions examined were only be those related to:

- Metacognitive goals.
- Task goals.
- Mentoring goals.
- Communicative acts and relations between acts that are not associated with a goal.
- Other categories (excluding incomplete utterance, pause critical, action excluded if not relevant).

Preceding learner interventions that were examined/recorded were:

- Metacognitive goals.
- Task goals.
- Mentoring goals.
- Communicative acts and relations between acts that are not associated with a goal.
- Other categories (excluding incomplete utterance, pause monitoring, pause critical, action excluded if not relevant).

The reason for the exclusion of some categories was that, although they assisted in allocating utterances to categories in the first analysis, it was not felt that these were feature or functionality that it was possible to implement in a computer-based teaching agent. If one of the excluded categories preceded a teacher goal and/or act, then the one-before that was taken, iteratively until an included learner goal and/or act was found.

This third analysis involved an examination of all included (as specified above) teacher goals and/or acts, and then stepping back through the analysed data to find the first occurrence of an included learner goal and/or act. If an act was associated with a goal (e.g. 'question' and 'probing') only the goal was recorded (e.g. 'probing'). This relationship was then captured on a spreadsheet. The approach used to record scores for a goal or act in the spreadsheet is illustrated below in Table A5.1:

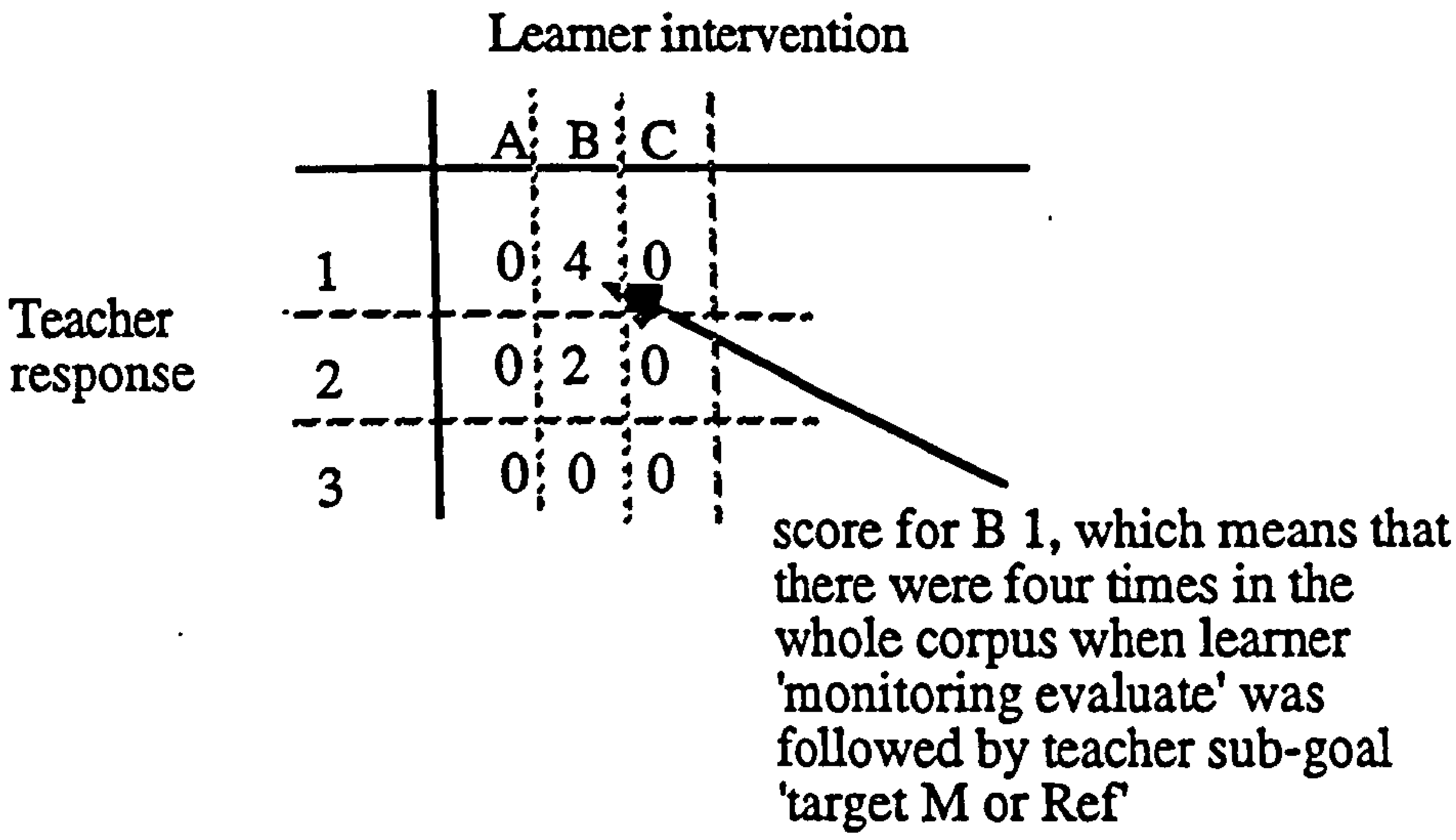

Figure A5.1. Example of spreadsheet score system.

The key used in the spreadsheet (which is reproduced in Section 3 of this appendix) and in Figures A5.2 and A5.3, is shown in Table A5.1. LA = learner and TA = teacher. The columns in Table A5.1 are cell references, as explained in the above example. The listing of the results taken form the spreadsheet (and placed into a Table form) is given in Section 3 of this appendix. Learner utterances and actions that lead to a teacher intervention can be seen as providing detail of the exact way in which a teacher promotes creative reflection.

Table A5.1
Key used for spreadsheet columns (LA) and rows (TA)

LA	TA	
A	1	target M or Ref
B	2	monitoring evaluate
C	3	monitoring diagnose
D	4	reflect predict
E	5	reflect imagine opportunity
F	6	task
G	7	critical judgement
H	8	critical probing
I	9	critical challenging
J	10	critical clarification
K	11	critical give reasons
L	12	critical give evidence
M	13	creative imagine opportunity
N	14	creative make prediction
O	15	creative accurate prediction
P	16	collaboration listen others
Q	17	motivation intrinsic
R	18	motivation extrinsic
S	19	motivation encouragement
T	20	assertion
U	21	assertion confirmation
V	22	accept
W	23	accept confirm
X	24	offer
Y	25	offer continue
Z	26	question
AA	27	reject
AB	28	request
AC	29	complete
AD	30	transform
AE	31	action
AF	32	other
AG	33	other continuation
AH	34	other may be in difficulty
AI	35	other not accept yet
AJ	36	other retraction
AK	37	other dialogue management

The key for the category numbers used in the spreadsheet, and in Figures A5.2 and A5.3, are shown in Table A5.1 above.

2. Results of third analysis

Table A5.2 below shows the learner intervention scores achieved for the 37 categories (the category numbers refer to the TA column in Table A5.1, these figures are taken form the spreadsheet column totals).

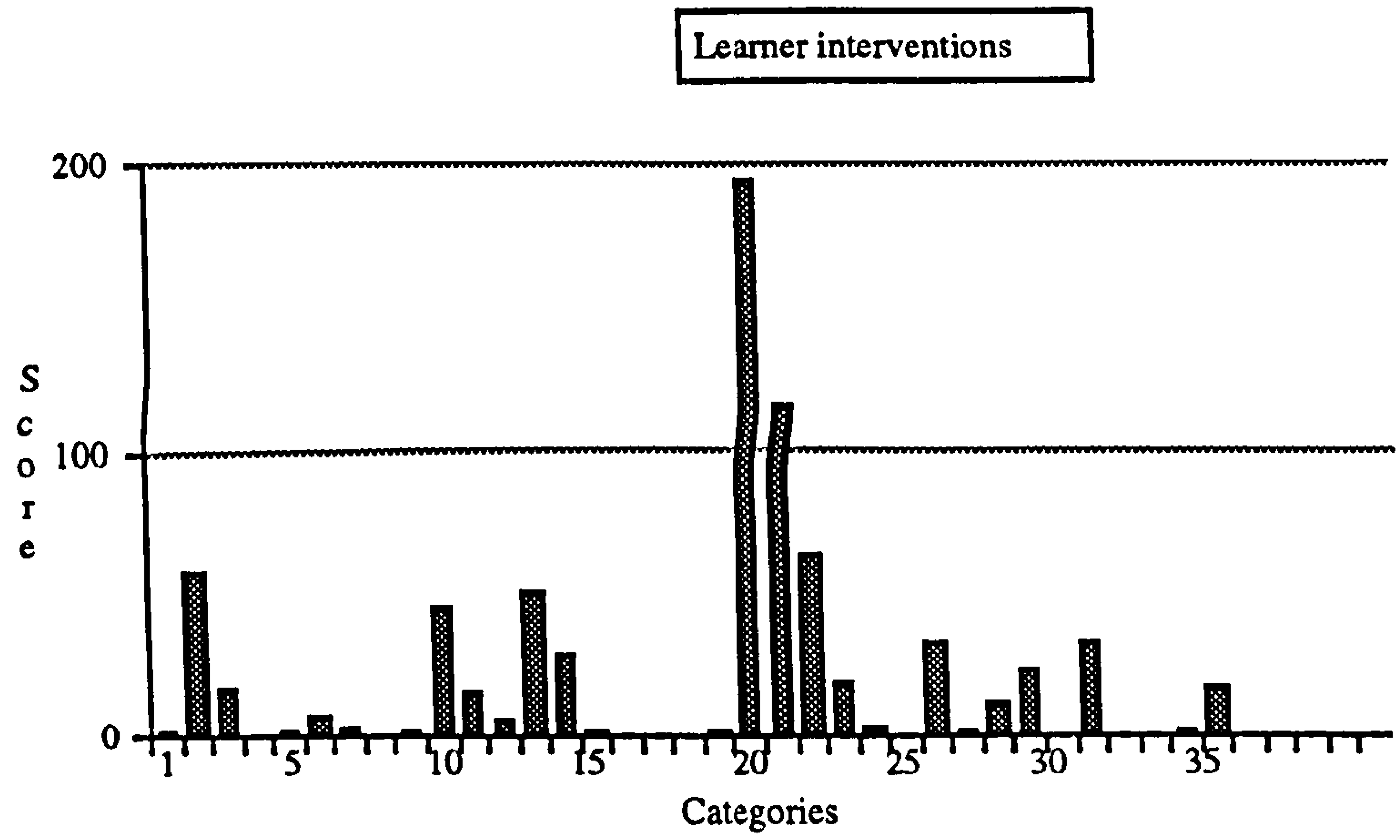

Figure A5.2. Learner intervention scores.

Table A5.3 below shows the learner intervention scores achieved for the 37 categories (these figures are taken form the spreadsheet row totals).

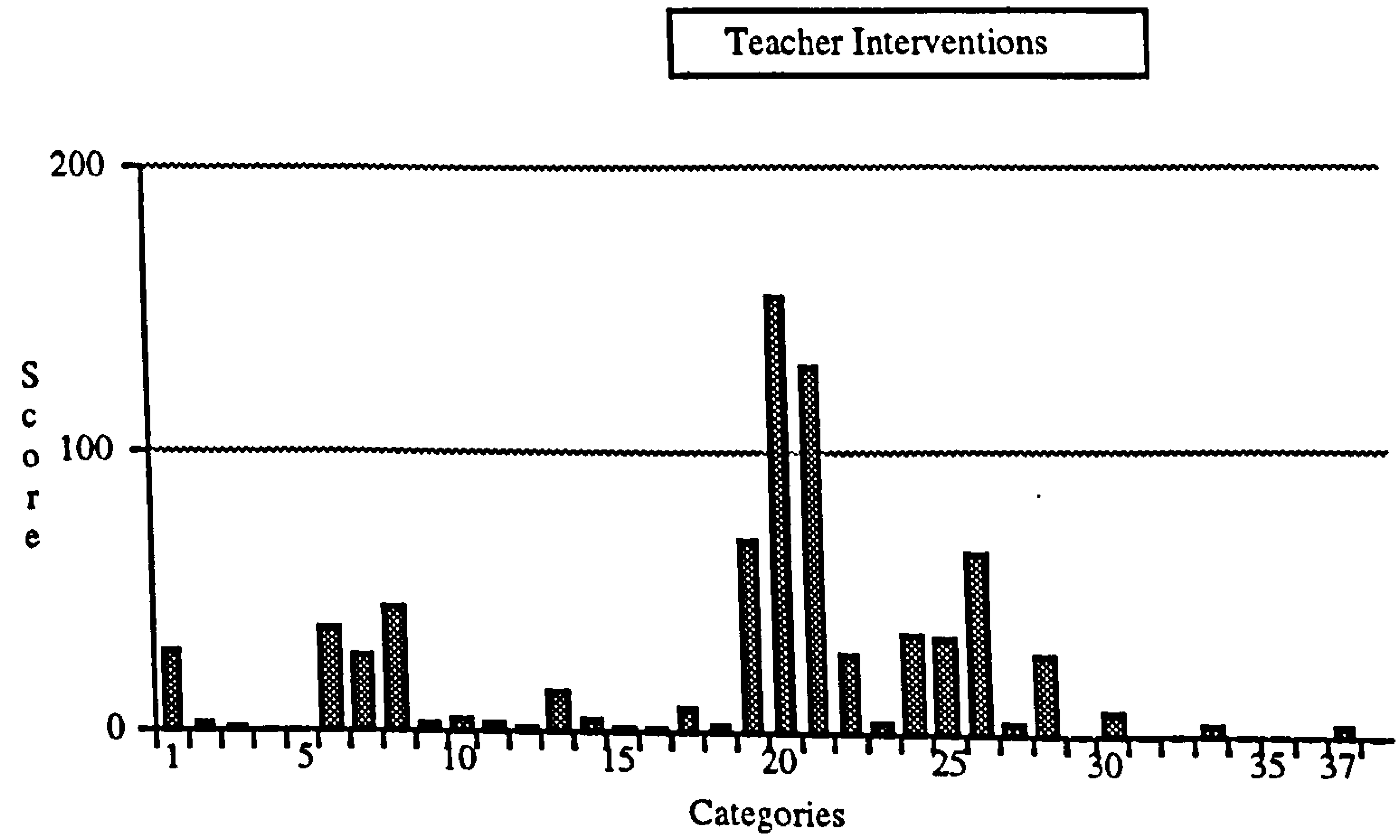

Figure A5.3. Teacher intervention scores.

Figures A5.2 and A5.3 exhibit a cluster of activity around assertion (category 20) and assertion confirmation (category 21) acts, which are by far the most often used of the 37 categories. This point is well illustrated in Table A5.2, which it should be noted is not the spreadsheet, instead it gives the total scores for the most common learner interventions and teacher responses (which are taken from the spreadsheet row and column totals).

Table A5.2.
Most common learner interventions and teacher responses

rank	LA intervention	score	TA response	score
1	assertion	194	assertion	155
2	assertion confirmation	116	assertion confirmation	130
3	accept	64	motivation encouragement	69
4	monitoring evaluate	59	question	64
5	creative imagine opportunity	52	critical probing	44
6	critical clarification	46	task	37
7	action	33	offer	36
8	question	33	offer continue	34
9	creative make prediction	28	target M or Ref	29
10	complete	23	accept	29
11	accept confirm	19	request	28
12	not accept yet	17	critical judgement	27
13	monitoring diagnose	17	creative imagine opportunity	14
14	critical give reasons	16	transform	8

Table A5.2 shows some results from analysis 3. The top 14 scores shown in Table A5.2 for learner interventions represent 95% of all interventions made by the learner. The most often used interactive goals by the learner were (in descending order): 'monitoring evaluate', 'creative imagine opportunity', 'critical clarification', 'creative make prediction', 'monitoring diagnose' and 'critical give reasons'. The top two learner goals were particularly well used, which is being interpreted as a sign that the interactions were healthy in terms of the learner's thinking about (i.e. monitoring) their own creativity.

The top 14 scores for the teacher (TA) interventions in Table A5.2 represent 93% of the total score for all responses made by the teacher. The most often used interactive goals by the teacher were (in descending order): 'motivation encouragement', 'critical probing', 'target M or Ref', 'critical judgement' and 'creative imagine opportunity'. The pedagogical 'task goal' was used 37 times. Table A5.2 shows that after 'motivation encouragement', 'critical probing' were the teacher's most often used interactive goal response. Table A5.2 confirms the first analysis finding that 'target M or Ref' is an important interactive goal for promoting metacognition.

Table A5.3
Most popular interactions
(only columns or rows with a score in that was >=10 were included here)

	LA intervention							
TA response	assertion	assertion confirma -tion	question	monitor evaluate	accept	critical clarificat -ion	creative predict-ion	creative imagine opport.
assertion confirmation	**56**	10	0	**20**	1	13	4	**10**
assertion	39	**35**	**22**	7	13	3	0	7
question	23	10	1	3	6	4	1	5
critical probing	16	6	0	3	3	5	3	5
task	9	15	1	1	3	2	0	1
offer continue	2	6	2	0	**15**	0	0	1
motivation encourage	15	4	0	5	1	**14**	**14**	7

The 15 interaction combination shown in Table A5.3 are taken from the spreadsheet (see Section 3 of this appendix). Only columns or rows in the spreadsheet with a score that was greater than or equal to 10 were included in Table A5.3 (this was a done in an attempt to make the data manageable). Table A5.3 shows scores for 56 learner intervention to teacher response combinations. Highest score for each column are in bold. This set of combinations (i.e. those recorded in Table A5.3) represent 45% of the total number of interactions recorded on the spreadsheet.

3. Spreadsheet scores from third analysis

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	0	4	0	0	1	0	0	0	0	1	0	0	1
2	0	2	0	0	0	0	0	0	0	0	1	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	1
4	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	1	0	0	0	0	0	0	0	2	1	0	1
7	0	6	0	0	0	1	0	0	0	1	0	1	3
8	0	3	0	0	0	0	0	0	0	5	0	0	5
9	0	1	0	0	0	0	0	0	0	0	0	0	2
10	0	1	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	1	0	0	0
12	0	0	0	0	0	0	0	0	0	0	1	0	0
13	0	2	1	0	0	0	0	0	0	0	0	0	0
14	0	1	0	0	0	0	1	0	0	0	0	0	0
15	0	1	0	0	0	0	0	0	0	0	0	0	0
16	0	1	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	5	2	0	0	0	1	0	1	14	3	1	7
20	1	7	2	0	0	3	0	0	0	3	1	2	7
21	0	20	6	0	0	1	1	0	0	13	6	1	10
22	0	0	1	0	0	0	0	0	0	0	2	0	5
23	0	0	1	0	0	0	0	0	0	0	0	0	2
24	0	1	2	0	0	0	0	0	0	1	0	0	1
25	0	0	0	0	0	0	0	0	0	0	0	0	1
26	0	3	2	0	0	0	0	0	0	4	1	1	5
27	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	2	0	0	0	0	0	0	1
29	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	1	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	1	59	17	0	1	7	3	0	1	46	16	6	52

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	2	0	0	0	0	0	5	3	0	2	0	0	1
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	9	15	3	3	0	0	1
7	1	0	0	0	0	0	2	3	1	0	0	0	0
8	3	0	0	0	0	0	16	6	3	1	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	1	1	1	0	0	0	0
11	0	0	0	0	0	0	1	0	0	0	0	0	0
12	0	0	0	0	0	0	0	1	0	0	0	0	0
13	1	0	0	0	0	0	2	3	1	1	0	0	0
14	0	0	0	0	0	0	0	1	0	0	0	0	1
15	0	1	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	.0
17	0	0	0	0	0	0	2	3	1	1	0	0	0
18	0	0	0	0	0	0	0	1	0	0	0	0	1
19	14	0	0	0	0	0	15	4	1	0	0	0	0
20	0	0	0	0	0	0	39	35	13	3	0	0	22
21	4	0	0	0	0	0	56	10	1	0	0	0	0
22	0	0	0	0	0	0	1	1	1	0	3	0	0
23	0	0	0	0	0	0	0	0	1	0	0	0	0
24	2	0	0	0	0	0	8	4	4	0	0	0	3
25	0	0	0	0	0	1	2	6	15	5	0	0	2
26	1	0	0	0	0	0	23	10	6	1	0	0	1
27	0	0	0	0	0	0	3	0	0	0	0	0	0
28	0	0	0	0	0	0	5	5	8	0	0	0	1
29	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	2	1	2	1	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	1	2	2	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	1	1	0	1	0	0	0
total (cont)	28	1	0	0	0	1	194	116	64	19	3	0	33

	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	total
1	0	0	2	0	5	0	0	0	2	0	0	29
2	0	0	0	0	0	0	0	0	0	0	0	3
3	0	0	0	0	0	0	0	0	0	0	0	1
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	1	0	0	37
7	0	0	0	0	7	0	0	0	1	0	0	27
8	0	0	0	0	2	0	0	0	0	0	0	44
9	0	0	0	0	0	0	0	0	0	0	0	3
10	0	0	0	0	0	0	0	0	0	0	0	4
11	0	0	0	0	1	0	0	0	0	0	0	3
12	0	0	0	0	0	0	0	0	0	0	0	2
13	0	0	1	0	1	0	0	0	1	0	0	14
14	0	0	0	0	1	0	0	0	0	0	0	5
15	0	0	0	0	0	0	0	0	0	0	0	2
16	0	0	0	0	0	0	0	0	0	0	0	1
17	0	0	0	0	1	0	0	0	0	0	0	8
18	0	0	1	0	0	0	0	0	0	0	0	3
19	0	0	0	0	1	0	0	0	0	0	0	69
20	0	0	4	0	4	0	0	1	8	0	0	155
21	0	0	1	0	0	0	0	0	0	0	0	130
22	0	7	8	0	0	0	0	0	0	0	0	29
23	0	0	0	0	0	0	0	0	0	0	0	4
24	0	1	2	0	4	0	0	1	2	0	0	36
25	0	0	0	0	0	0	0	0	2	0	0	34
26	1	1	1	0	3	0	0	0	0	0	0	64
27	0	0	1	0	0	0	0	0	0	0	0	4
28	0	2	2	0	2	0	0	0	0	0	0	28
29	0	0	0	0	0	0	0	0	0	0	0	0
30	1	0	0	0	0	0	0	0	0	0	0	8
31	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	5
34	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	1	0	0	0	0	0	0	4
total	2	11	23	0	33	0	0	2	17	0	0	756

(cont)

4. Discussion of third analysis

'Target M or Ref' (the asking of open-ended questions, e.g. "Was that what you intended?") appears to be an important intervention for promoting 'creative imagine opportunity'. Analysis 3 (Table A5.2) confirmed the first and second analysis finding (see Section 5.4.1) that 'target M or Ref' is an important interactive goal for promoting metacognition (response score in Table A5.2 = 29). Table A5.2 also shows that a relatively limited number of teacher goals are required to make a response to a learner.

The high scores for the acts 'assertion' and 'assertion confirmation' in Table 5.3 (Chapter 5) are confirmed in Table A5.3. Certain combinations are of interest with respect to the interactive goals:

- When the learner made a monitoring evaluate utterance, the teacher's most common response was 'assertion confirmation'.
- When the learner made a 'critical clarification' utterance, the teacher's most common response was either (i) 'assertion confirmation' or (ii) 'motivation encouragement'. This confirms the importance of motivation as a way of helping the session to flow smoothly.
- When the learner made a 'creative make prediction' utterance, the teacher's most common response was 'motivation encouragement'. Again, motivation seems a key initial response.

- On 16 of the occasions when the learner made an 'assertion' utterance, the teacher's response was to use 'critical probing'.
- When a learner asks a 'question' the most common teacher response is to make an 'assertion'.

One drawback with Table A5.3 and the spreadsheet is that although an initial response to a learner may be 'motivation encourage' it is the sequence of events that then follow this that may be more informative. Analysis four and five redress this imbalance. However, analysis 3 did generate raw data that was put to good use in the preference mechanism of the implemented teaching agent described in Chapter 6.

Appendix 6 - Fourth Analysis, Post-Experimental Cue Details

1. Detail of fourth analysis approach

In Chapter 1 (Section 1.1.2) we pointed out that is possible to object to our proposed line of inquiry (i.e. our approach to system design) on a number of theoretical grounds. One objection would be to cast doubt on the use of dialogue data as an indicator of the beliefs of participants in a dialogue, i.e. coding and analysing verbal dialogues may fail to take into account either the participants' intentions or the (personal) meaning system of which they may be a part. We also pointed out that, this objection can be addressed by the use of theory to incorporate, amongst other things, the goals of the speaker (Draper and Anderson, 1991, p. 105). Furthermore, we pointed out that the use of structured interviewing, in conjunction with an analysis of the dialogue data, can help uncover the goals of the dialogue participants.

Consequently, in the fourth analysis post-experimental cue data was incorporated with the interaction data to enhance the analysis (i.e. to include the cognitive dimension in terms of goals and intentions of the interacting agents). For a full discussion of this research method see Chapter 4. Three extended examples of this approach to analysis are given below.

2. Results from analysis four

2.1 Example 1

The analysis discussion below refers to Table 4.1 (in Section 4.2.2) and Table A6.1. This interaction example is taken form session 1 of our empirical study. At LA6 in Table 4.1 there is plenty of time for the learner to reflect, the interview data at LA6 gives an indication of the learner's thought processes at that moment in time. The introduction of an extra component for reflection (tempo) by the teacher at TA2 and TA3 seems to have successfully caused reflection, as we believe the post-experimental interview data at LA6 illustrates. Interestingly, the interview data shows that the learner brings into his considerations 'what he thinks the teacher might be expecting him to do', i.e. the student is building up a model of the teacher's expectations. This was also found in session 4 and is what we are calling reciprocal modelling in this thesis (Section 5.4.3 has already elaborated on this result using extracts from Table 4.1). In this example, once the teacher's expectations have been inferred by the learner, the approach seems to be one of trying confound those expectations, to surprise! This is evidenced at LA8 where the learner suggests that the tempo could be "quicker", the opposite to what the learner thinks the teacher wishes him to do.

Although the learner has done something unexpected, the full power of what he has done is not made clear to both interaction participants until a few minutes later, in the interaction shown in Table A6.1. At utterance TA36 the teacher now seems to understand the learner's usage of the leaps. At TA39 the teacher draws an analogy between the learner's phrase and the music of Bach. At LA42 the learner has extended his self-explanation of his creative activity to encompass the second large leap. It has taken some time for the learner to put into words what his creative intentions were. However, the effort seems to have been worth it. Later in the session the teacher comments: "... I must say that I'm quite surprised that you've done ... I find that quite ... a very novel way of treating the solo line. Umm, particularly with a repeated sequence." 'Reflect imagine opportunity' at LA41 seems to have been first brought about by 'target M or Ref' at TA2 and again by a critical judgement at TA39.

Table A6.1
Example 1 (pt 2) of post-experimental cue analysis

TA = Teaching Agent, LA = Learning Agent

Agent-utterance	goal	act	other	commentary and post-experimental cue data
LA35: No, I see it as, as something totally different, not part of the // phrase-eology	critical give reasons	assertion		Comment: Similar to LA24, except a response to give evidence. The reason that 28 is not the end of a phrase being that the 28 is 'not part of the phrase-eology'
TA36: *Not part, ahh right.* =		accept		Transcription comment: Italics indicates vocal stress on what is said. Comment: The teacher now seems to understand the learner's usage of the leaps, (the stress on what is said seems to support this interpretation).
LA37: Do you see what I mean?	critical clarification	question		Comment: the learner wants to know if the teacher has understood his intention correctly.
LA38: So that [POINTS TO 28] (phrase stands by) itself.	above goal still active	assertion	action	
=[				Transcription comment: Indicates that LA38 and TA39 simultaneously latch (both start to speak at the same time).
TA39: So this, is it, almost, you know like in a Bach's suite having a, like, like, like in a solo suite where you have a, perhaps a figure playing at a different octave, which gives the impression of there's another voice?	critical judgement	assertion		Comment: The teacher draws a parallel between the learner's phrase and the music of Bach. Because this utterance is using criteria (the music of Bach) it is coded as a judgement.
LA40: Yeah,		assertion confirm-ation		
LA41: I (5.0) I, I see,	reflect imagine opportunity			Comment: the learner thinks about the Bach example.
LA42: I see [USES TWO FINGERS TO POINT AT 28 AND 24] them as, as if they had been put on top, as if they // are something else=	creative imagine opportunity	assertion	action	Comment: the learner has extended the explanation of his creative activity to encompass the second large leap.

2.2 Example 2

In Table A6.2, the first sentence of the interview data at LA6 suggests that the learner never thinks beyond the section he is composing, which would seem to make him an ideal candidate for practice at creative reflection and confirms some of the findings of earlier studies that were used as design considerations for Coleridge (see Chapter 5, Section 5.2). It also confirms the need for a computer-based teaching agent for Coleridge that will allow learners to practice creative reflection.

Table A6.2
Example 2 of post-experimental cue analysis

TA = Teaching Agent, LA = Learning Agent

Agent-utterance	goal	act	other	commentary and post-experimental cue data
TA3: See if you can create something now which has very definite sections to it.	above goal still active	offer contin-ued		Comment: This and TA5 are examples of the heuristic of music as it is taught in relation to 'the potential that the choice of intervals provides for music to be sectionalised into phrases'.
LA4: [TYPES 0 SPACE IN DATA ENTRY AREA]		accept	action	Comment: By getting down to work the learner has implicitly accepted the teacher's offer.
TA5: I mean one section might be chromatic, the next section might have big leaps. I mean =		offer contin-ued		
LA6: =How many sections in it?	task	question		Interview data: The learner: "Well I don't usually think of how many sections from the start. Emm, I just thought maybe the first section to, to maybe set the key. And then a middle section with a bit of chromaticism. And there more or less to where I started for the third section. So three sections."
TA7: I mean you can do whatever you feel but, emm experiment a little bit with emm, it's it's just one, one way way of working.		request		Comment: This is coded as a request because the teacher wants the learner to decide how many sections to compose.
TA8: Because for me as the listener your first composition wasn't immediately clear the first time. I had to kind of puzzle my way into it.	judgement	assertion		Comment: The reason for this judgement seems clearer with the data given at LA6, where the learner suggested that he didn't plan ahead. It is fair to assume that he does not consider the hearer when composing, as the teacher is asserting here.

2.3 Example 3

Table A6.3 gives a good example of how the teacher tries to lead the learner into imagining an opportunity, which she does. However, she imagines something different to what the teacher has in mind (a good example of the fact that there is no one correct solution in music composition problem solving). At TA3 the teacher is giving the learner the opportunity to imagine a creative opportunity, rather than simply making a judgement by saying 'I think it's too symmetrical' (the interview data indicates that this is what the teacher was thinking, i.e. this was the intention behind his utterance). TA3 is open-ended questioning but is specific (it requests definite sections), hence it is coded 'creative imagine opportunity'. TA8 could have been coded as 'creative imagine opportunity', but as it is more generic (no constraint such as 'if you could make one change'), it is therefore coded as 'target M or Ref' (this may be debatable, the two categories are very close).

Table A6.3
Example 3 of post-experimental cue analysis

TA = Teaching Agent, LA = Learning Agent

Agent-utterance	goal	act	other	commentary and post-experimental cue data
TA1: OK, so you're getting the hang of using this.	creative accurate prediction	ass-conf. assertion		Comment: Following her second attempt, the learner has just commented that she is satisfied that the phrase sounds how she imagined it would (i.e. she made an accurate prediction). In this utterance the teacher 'assertion-confirms' (OK) and makes a positive 'assertion' about the learner's ability at 'creative accurate prediction'
TA2: [PLAYS THE PHRASE AGAIN].		action		Comment: Given the interview data given below at TA3, my guess is that the teacher is listening to the phrase again to confirm that there is something in the phrase that he wants to change.
TA3: Right, if you could make one change to that what would it be?	creative imagine opportunity	question		Interview data: The teacher: "Yes. Umm, I was, I was conscious of, of something I wanted to change. Err, and I was surprised that she hadn't seen it, as I was, I was hoping that she would, emm, she would come up with something that would, emm possibly break up even more the sort of symmetry, that she'd established in those phrases. Because it was quite severe. What she came up with was quite a surprise: a randomised ending. I didn't expect that at all." Comment: The teacher is giving the learner the opportunity to imagine a creative opportunity, rather than simply making a judgement by saying 'I think it's too symmetrical'. This is open-ended questioning.

Table A6.3 (Continued)

Agent-utterance	goal	act	other	commentary and post-experimental cue data
LA4: (1.3) Emm,	reflect imagine opportunity			Interview data: The learner: "When I did it the first time, I wasn't sure what I was going to get out of it. But once I'd started to hear it a few times and I could look at it again on the screen, I could realise that, I didn't really want that phrase, I could maybe change it to something different." Comment: There is a pause for reflection about an opportunity. The above data indicates that the learner is considering a change.
LA5: the last section.	creative imagine opportunity	assertion		Comment: the learner decides that the opportunity for change is in the last section of her composition.
TA6: The last section.		assertion confirm-ation		
TA7: [CLICKS AT END OF THIRD DATA LINE]		action		
TA8: What would you do with it?	target M or Ref	question		Comment: This could have been coded as Creative Imagine Opportunity, but as it is more generic (no constraint such as 'if you could make one change') it is coded as target M or Ref (this may be debatable, the two categories are very close).
LA9: (1.6)	reflect imagine opportunity			Comment: Another point of reflection.
LA10: Maybe something completely random.	creative imagine opportunity	offer		Comment: As the interview data below shows (not shown here), the learner comes up with a novel idea as an offer of how she would like her third section to be changed (i.e. how to proceed next).

Appendix 7 - Fifth Analysis, Mentoring Stages Details

1. Detail of fifth analysis approach

In the fifth analysis, print-outs of the goals (communicative act were excluded from this analysis) for each session were analysed to see if any sequence within a session could be detected (all analysis and annotations were by hand because the qualitative analysis software package used does not provide easy list manipulation or text export facilities).

2. Results of fifth analysis approach

10 mentoring stages have been extrapolated. Table A7.1 gives a summary of this analysis, 'X' indicates that a goal was identified for a session. Stage 3 and 8 are only present in two out of four of the sessions, and stage 9 was an additional listening task introduced by the mentor to give the learners an example of how the musical transformations they were working on could be used in a full composition (an example of the mentor's own work was used). If we drop these three stages (i.e. 3, 8 and 9) then we would claim that, based on the analysis shown in Table A7.1, that there is evidence for the seven mentoring stages, in the order shown, for all session described in Section 5.4.4 of this thesis.

Table A7.1
Ten candidate mentoring stages

Stage/goal	session 1	session 2	session 3	session 4
1. Open session with motivation	X	missing	X	X
intrinsic motivation	X	missing	missing	missing
extrinsic motivation	X	missing	X	X
2. Introduce task and initial probing	X	X	X	X
3. Initial learner activity	X	missing	missing	X
monitoring evaluate	X	missing	missing	missing
creative imagine opportunity	X	missing	missing	X
creative make prediction	missing	missing	missing	X
4. Initial Target M or Ref, leading to the learner satisfying:	X	X	X	X
monitoring evaluate	X	X	X	X
monitoring diagnose	X	missing	missing	X
creative imagine opportunity	X	missing	X	X
creative make prediction	missing	missing	X	missing
5. Mentor led critical thinking, using	X	X	X	X
probing	X	X	X	X
judgement	X	X	X	X
give reasons	X	missing	missing	missing
6.1 Target M or Ref, leading to the learner satisfying:	X	X	X	X
monitoring evaluate	X	X	X	X
monitoring diagnose	X	missing	missing	missing
creative imagine opportunity	X	missing	X	missing
creative make prediction	X	missing	missing	missing

Table A7.1 (Continued)

Stage/goal	session 1	session 2	session 3	session 4
creative make accurate prediction	missing	missing	X	missing
6.2 Target M or Ref, leading to the learner satisfying:	X	missing	X	X
monitoring evaluate	X	missing	X	missing
monitoring diagnose	missing	missing	missing	X
creative imagine opportunity	X	missing	X	X
creative make prediction	missing	missing	missing	missing
creative make accurate prediction	missing	missing	missing	missing
6.3 Target M or Ref, leading to the learner satisfying:	X	missing	X	X
monitoring evaluate	missing	missing	X	X
monitoring diagnose	missing	missing	missing	X
creative imagine opportunity	X	missing	X	X
creative make prediction	missing	missing	missing	missing
creative make accurate prediction	missing	missing	missing	missing
6.4 Target M or Ref, leading to the learner satisfying:	missing	missing	missing	X
monitoring evaluate	missing	missing	missing	X
monitoring diagnose	missing	missing	missing	missing
creative imagine opportunity	missing	missing	missing	X
creative make prediction	missing	missing	missing	missing
creative make accurate prediction	missing	missing	missing	missing
7. Mentor probing leads to the learner satisfying:	X	X	missing	X
critical thinking	X	missing	missing	missing
creative imagine opportunity	X	missing	missing	X
prediction	X	X	missing	missing
8. Target M or Ref, leading to the learner satisfying:	X	X	missing	missing
monitoring	X	X	missing	missing
creative imagine opportunity	X	X	missing	missing
9. New listen and comment task	X	X	X	X
10. End session	X	X	X	X

Appendix 8 - State Transition Network Details

The sixth analysis described in Chapter 5 involved the mapping-out of various state transition networks to represent the sequence in which goals are pursued and the acts that are used to achieve them. Analysis six took as its starting point the seven stages identified in analysis five.

1. Task goal network diagram

Figure A8.1 shows the network diagram for Task Goals.

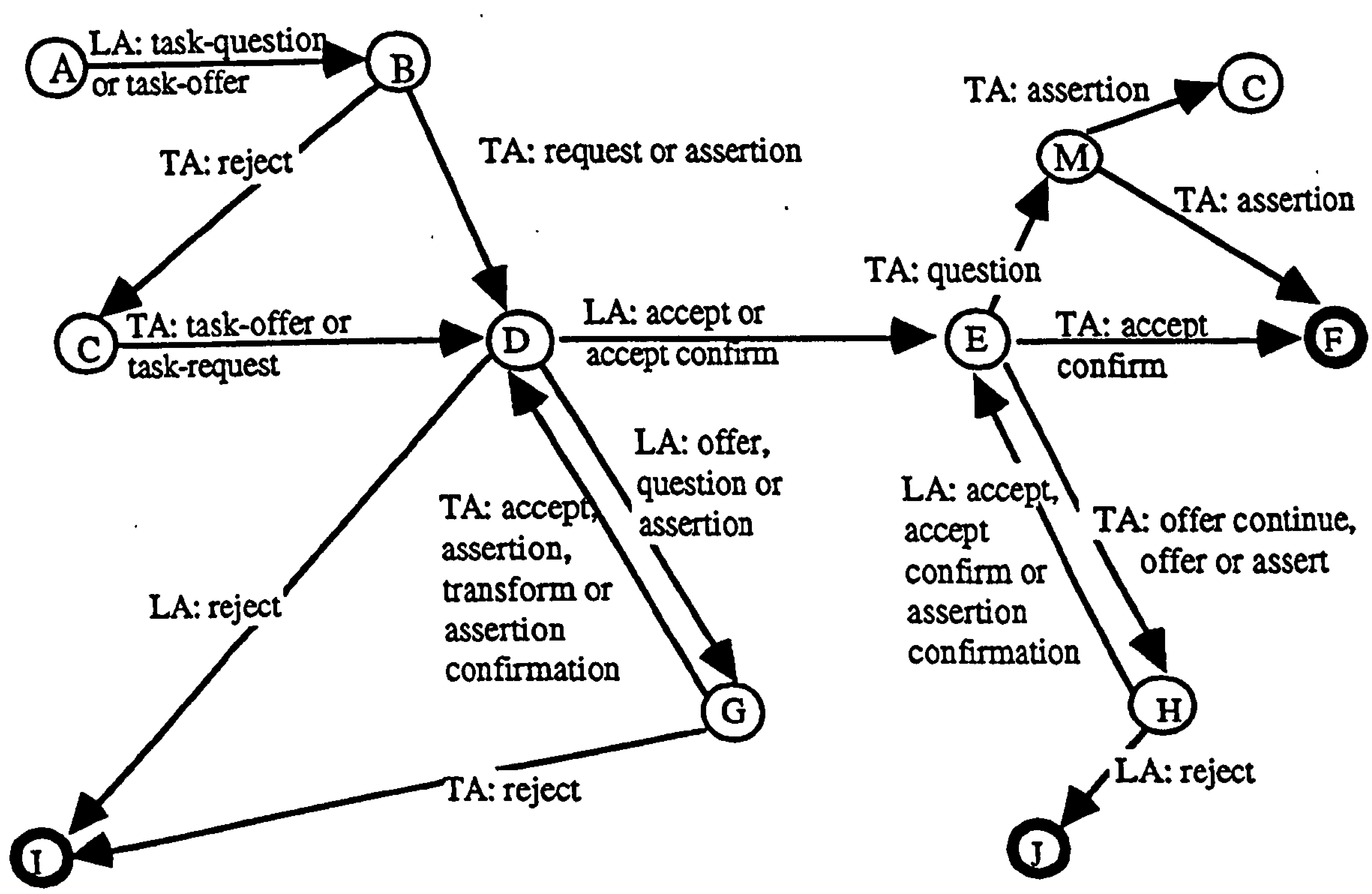

Figure A8.1. Network of acts and relations for task goal.

In Figure A8.1, taking the agents from state C to state D, the teacher has made an 'offer' of how to proceed or some 'request' regarding a task goal. In the normal course of events, the learner 'accepts' the teacher's 'offer/request' regarding a task goal (perhaps performing some 'action' and moving to the state labelled E in Figure A8.1). If the teaching agent declares that it is satisfied with 'accept confirm', the interaction episode reaches a successful completion and both agents reach state F. However, at states D and E things may not follow a 'normal' course of events. At state D the learner may 'reject' the task, we therefore have:

- The learner may make a counter 'offer' taking the agents to state G. The teacher may 'reject' this 'offer' and the agents reach state I; or the teacher may 'accept' the learner's 'offer' thus moving the agents to state D (the learner would then 'accept confirm' moving the agents to state E); or the teacher may 'transform' its own offer taking into account the learner's 'offer' (taking the agents to state D).

- From state D the learner may ask a 'question' about the task, taking the agents to state G, the teacher may make an 'assertion' to answer the 'question' (taking the agents to state D).
- From state D the learner may make an 'assertion' regarding the task, taking the agents to state G, the teacher may then confirm this assertion or make a counter 'assertion' taking the agents back to state D.

At state E the teacher may either:

- 'Assert' (implicitly or directly) that a new goal is to be pursued and then go to the interaction state M. In this M state, other mentoring goals will be pursued to achieve the task goal. Once the task goal (more likely a task sub-goal) has been achieved by the learner, the teacher 'asserts' satisfactory completion of the goal and both agents return to state F or to state C to resume the task goal.
- Or continue to describe the 'offer', taking the agents to state H. The learner may at this point 'reject' the 'offer' and reach state J, or 'accept' it (which may involve more action by the learner) and return to state E.

Figure A8.1 state A also shows that the learner can initiate task interaction with a 'question' or an 'offer', thus taking the agents to state B. At this point the teacher can either make some 'assertion' regarding the 'question' or some 'request' regarding the 'offer', either act taking the agents to state D. Alternatively, from state B the teacher may 'reject' the learner's 'offer' and move the agents to state C (and pursue its own task goal).

Note that the network in Figure A8.1 has not been checked against all occurrences of task goal in the interaction data. Making the task goal network more empirically based than its present descriptive state would be a useful line to take with future research. However, Table A8.1 provides an example to illustrate the working of the network shown in Figure A8.1 as applied to interaction extracts from the first session of the study. Table A8.1 shows a simple example that starts from state A in Figure A8.1. The details in the right-hand column of the table map the route taken by the interaction, shown in the left column, through the network diagram. In this example state transitions D to E and E to F are implicit.

Table A8.1
Example 1 of network transitions for task goal (from session 1)

utterance	route through the network (Figure A8.1)
LA: [MOVES CLOSER TO KEYBOARD, TYPES: 0 SPACE -5] You don't need commas or anything?	state A --> LA: task-question --> state B
TA: No, just, just write the err, write transposition shift.	state B --> TA: request --> state D
	state D --> LA: accept(implicit) --> state E --> TA: accept confirm(implicit) --> state F

2. Mentoring and metacognitive goals state transition networks

This part of analysis six used the seven stages identified in analysis five as an organising framework. The seven state transition networks presented in this section are all empirically derived (they represent all the goals analysed, with a few exceptions which will be noted). Generally, most of the following networks describe the goals and sub-goals used in interaction (i.e. the high-level dialogue structure of the interactions).

2.1 Stage 1 - Open session

Figure A8.2 shows the first stage of mentoring. This stage was present in 3 out of the four sessions.

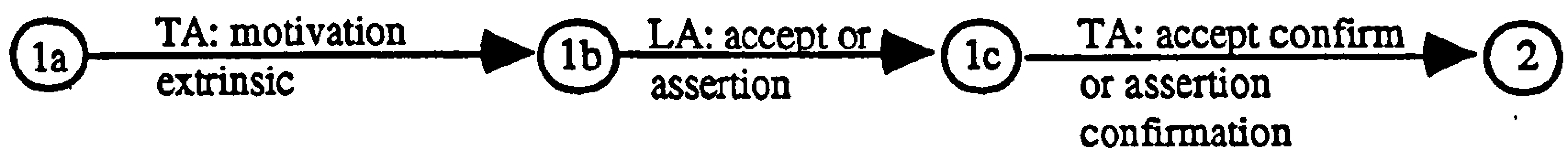

Figure A8.2. Stage 1 network for start session.

'Motivation extrinsic' is defined as providing a concrete reason for pursuing a task. In normal music classroom interaction extrinsic motivation to do work for the portfolio (which forms the basis for assessment) is a strong factor in getting undergraduate students to work on a task. In the study described in Chapter 5 of this thesis, the students were sent a short letter by the teacher giving an account of the benefits that they might gain from participating in the study (the full letter is in Section 3 of Appendix 3). Table A8.2 gives an example of extrinsic motivation from the start of session 4.

Table A8.2
Example of extrinsic motivation

utterance	route through the network (Figure A8.2)
TA: You've had a, had a read of my explanation?	state 1a --> TA: motivation extrinsic-question --> state 1b
	Comment: Reference to the letter in the interactions was taken to be an instance of extrinsic motivation.
LA: Yeah.	state 1b --> assertion --> state 1c
TA: So you know what we're doing.	state 1c --> assertion confirmation --> state 2

2.2 Stage 2 - Introduce task and initial probing

The network shown in Figure A8.3 covers all the goals observed in sessions 1 to 4 for the second mentoring stage ('explain task and initial probing') with the following minor provisos:

- Occasionally a goal is repeated in the interaction data, this is not represented in the network.
- In session 2, 3 and 4 this stage started at state 3. In session 1, 3 and 4 stage 2 ended at state 8. In session 2 it ended at state 6 after a number of iterations around states 3-4-5.
- In session 3 on one occasion the transition from state 5 to 3 was missing in the interaction.

Note that the several transitions of 'TA: Task' shown in Figure A8.3 are essentially a call to the task goal network shown in Figure A8.1. For example, moving from state 3, once the task goal has been satisfied the agents move on to state 3. Taken together, these two state transition networks (Figures A8.1 and A8.3) give a very clear representation of how task goals and other mentoring pedagogical goals are related. Basically, as was pointed out earlier (Chapter 3), one can be nested in the other.

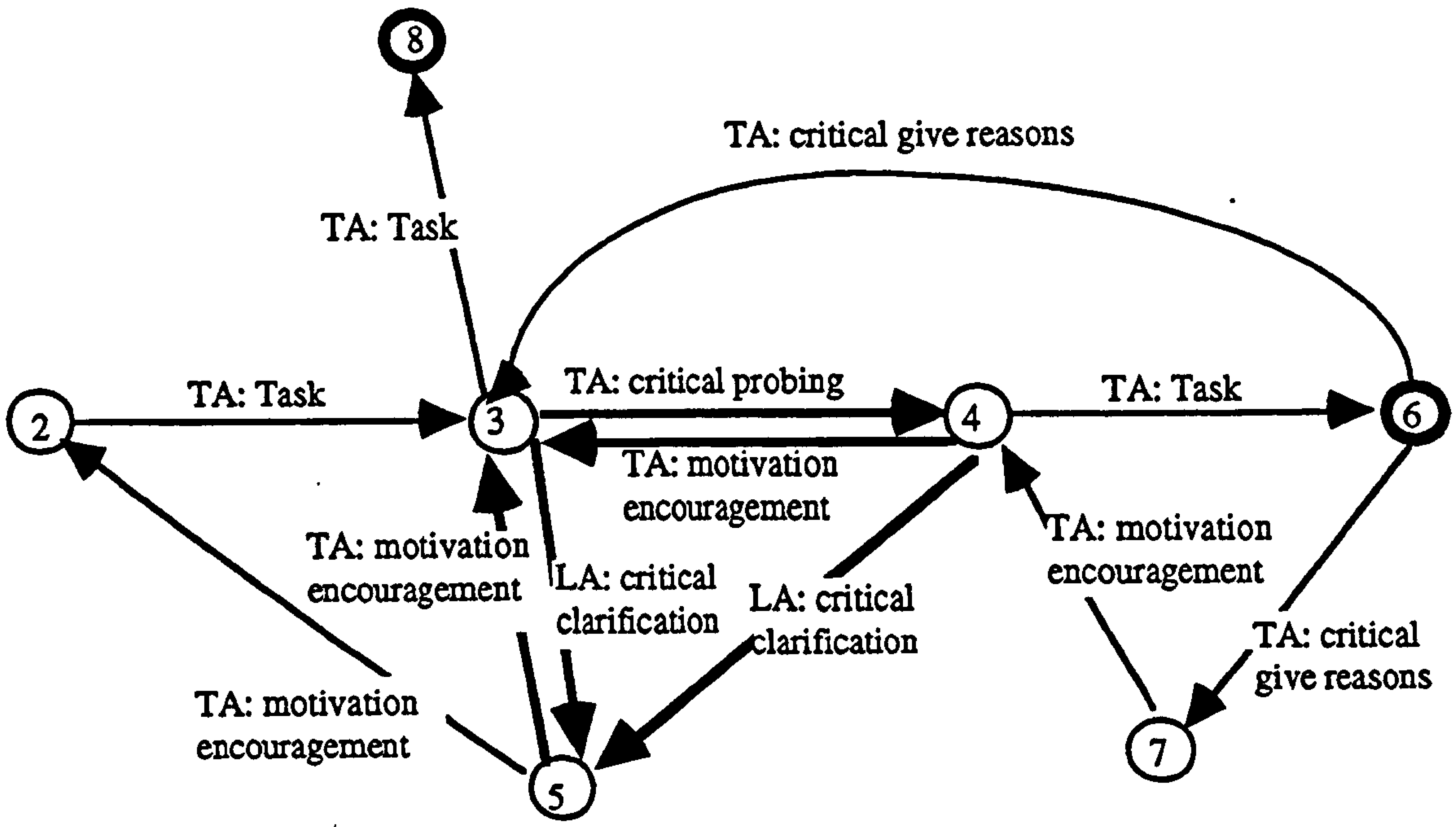

Figure A8.3. Stage 2 network for explain task and initial probing. (bold arrows represent frequently used transitions)

Table A8.3 gives a small example of part of stage 2 (taken from the start of session 3). Unlike the goals used to achieve transitions in stages 1 and 7 (i.e. open session and end session), which are relatively simple, the goals used in stages 2 to 6 are more complicated. For example, the first state transition shown for stage 2 in Figure A8.3 (i.e. state 3 to 4) can be achieved by the two communicative acts ('request' and 'question') shown in Table A8.4. Note that the primary act 'request' moves the agents to state 3.1 and 'question' moves the agents from state 3.1 to state 4. From this point on, only the interactive goals will be shown in the network analyses. (If only one primary act was used it is, however, shown in Tables A8.3 and A8.4).

Table A8.3
Example interaction for stage 2

utterance	route through the network (Figure A8.3)
TA: Can you emm, I want you to try and recall how you started off that exercise. Did you pick the four notes at random? Or did you choose them?	state 3 --> TA: probing--> state 4
LA: I picked the four notes a random by just by clicking on the keyboard // down the left-hand side. [THIS REFERS TO THE SCREEN OF THE SEQUENCER SOFTWARE]	state 4 --> LA: clarification-assertion --> state 5
TA: Right	state 5 --> TA: motivation encouragement-assertion confirmation --> state 3
TA: so there was no, thinking carefully sort of carefully 'oh this is, you know, this is going to be a motif?'	state 3 --> TA: probing-question --> state 4
LA: No just picked the notes.	state 4 --> LA: (above clarification goal still active)-assertion --> state 5

Table A8.4
Communicative acts used to achieve 'critical probing'

utterance	acts used to move from state 3 to 4 in Figure A8.3
TA: Can you emm, I want you to try and recall how you started off that exercise.	state 3 --> TA: request--> state 3.1
TA: Did you pick the four notes at random? Or did you choose them?	state 3.1 --> TA: question --> state 4

2.3 Stage 3 - Initial use of Target M or Ref

The network in Figure A8.4 covers all the goals observed in sessions 1 to 4 for the third stage ('initial use of target M or Ref') with the following minor provisos:

- Occasionally a goal is repeated, this is not represented.
- In session 1 the final state was 12, in session 2 this stage ended quickly at state 10, in session 3 the final state was 19, and in session 4 the final state was 16.

The goal sequence identified in analysis 2 (see Section 5.4.1), i.e. 'target M or Ref' leading to monitoring 'evaluate' then 'diagnose', is also evident in stage 5 (Figure A8.6). Note that this network is also given as an example in Section 5.4.4 of the thesis; please refer to that section for a discussion.

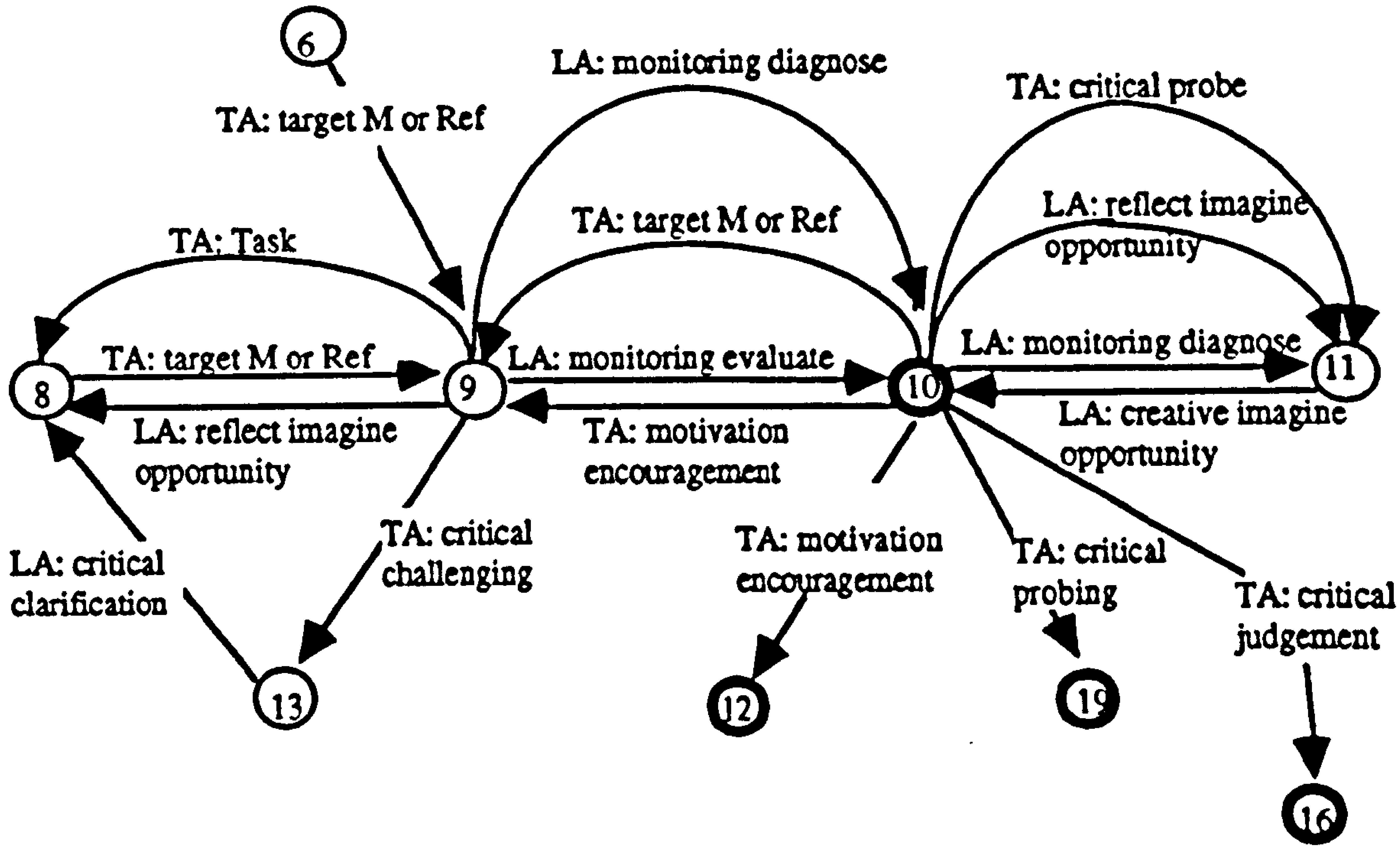

Figure A8.4. Stage 3 network for 'initial use of target M or Ref'.

2.4 Stage 4 - Mentor led critical thinking

The network shown in Figure A8.5 covers all the goals observed in sessions 1 to 4 for the fourth stage (mentor led critical thinking) with the minor proviso that occasionally in the interaction a goal is repeated, this is not represented in the network. In session 1 the final state was 17, in session 2 the final state was 29 (after a very limited critical stage), in session 3 the final state was 30, and in session 4 the final state was 27.

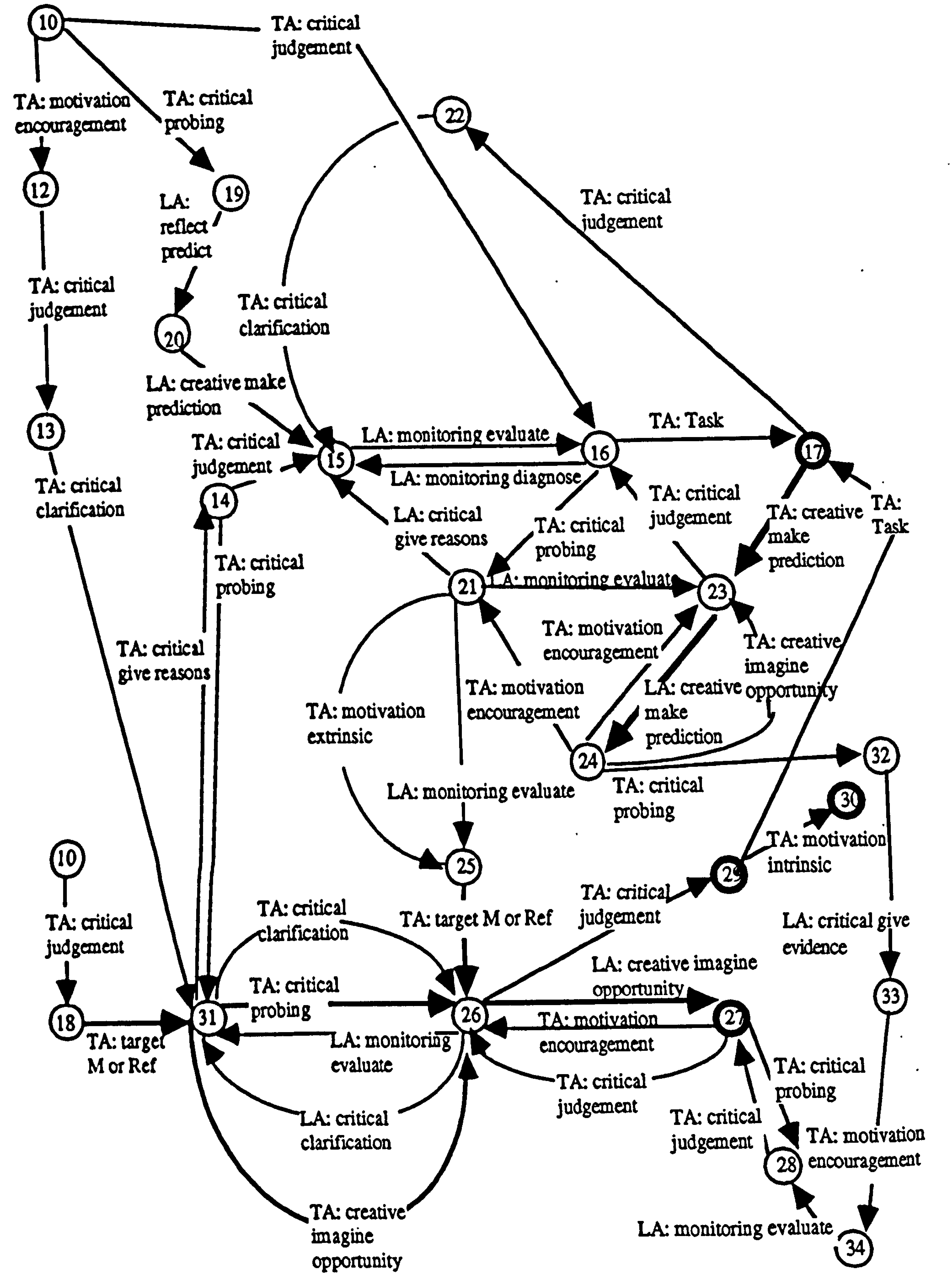

Figure A8.5. Stage 4 network for mentor led critical thinking.

Figure A8.5 at a glance shows that promoting critical thinking is complex. However, what emerged from the analysis was that there are many common routes through the network. We have group commonly used goals together where possible in the Figure

A8.5. In particular, the following goal-state transitions were heavily used (and are shown as bold arrows in Figure A8.5):

- state 17-23-24 centre on the learner making a creative prediction (this area in the network was used by sessions 3 and 4)
- states 31-26-27 centre on monitoring and learner 'creative imagine opportunity' (this area in the network was used by all 4 sessions).

It is interesting to note that three sessions start with 'critical judgement', the other with 'critical probing'. Also, 'target M or Ref' in this stage tends to initiate interactions related to 'creative imagine opportunity'.

2.5 Stage 5 - Target M or Ref used (iterate 3-4 times)

The network shown in Figure A8.6 covers all the goals observed in sessions 1 to 4 for the fifth stage ('iterative use of target M or Ref') with the minor proviso that occasionally in the interaction a goal is repeated, this is not represented in the network. The network does not represent 6 goals used in session 2. There is one goal ('target M or Ref') missing in the interaction in session 3 (put another way, the network adds an extra goal for session 3). This stage was repeated in most session (four times in session 4, only once in session 2). Because it was called a number of consecutive times, this stage has many end states (which are not shown in Figure A8.6).

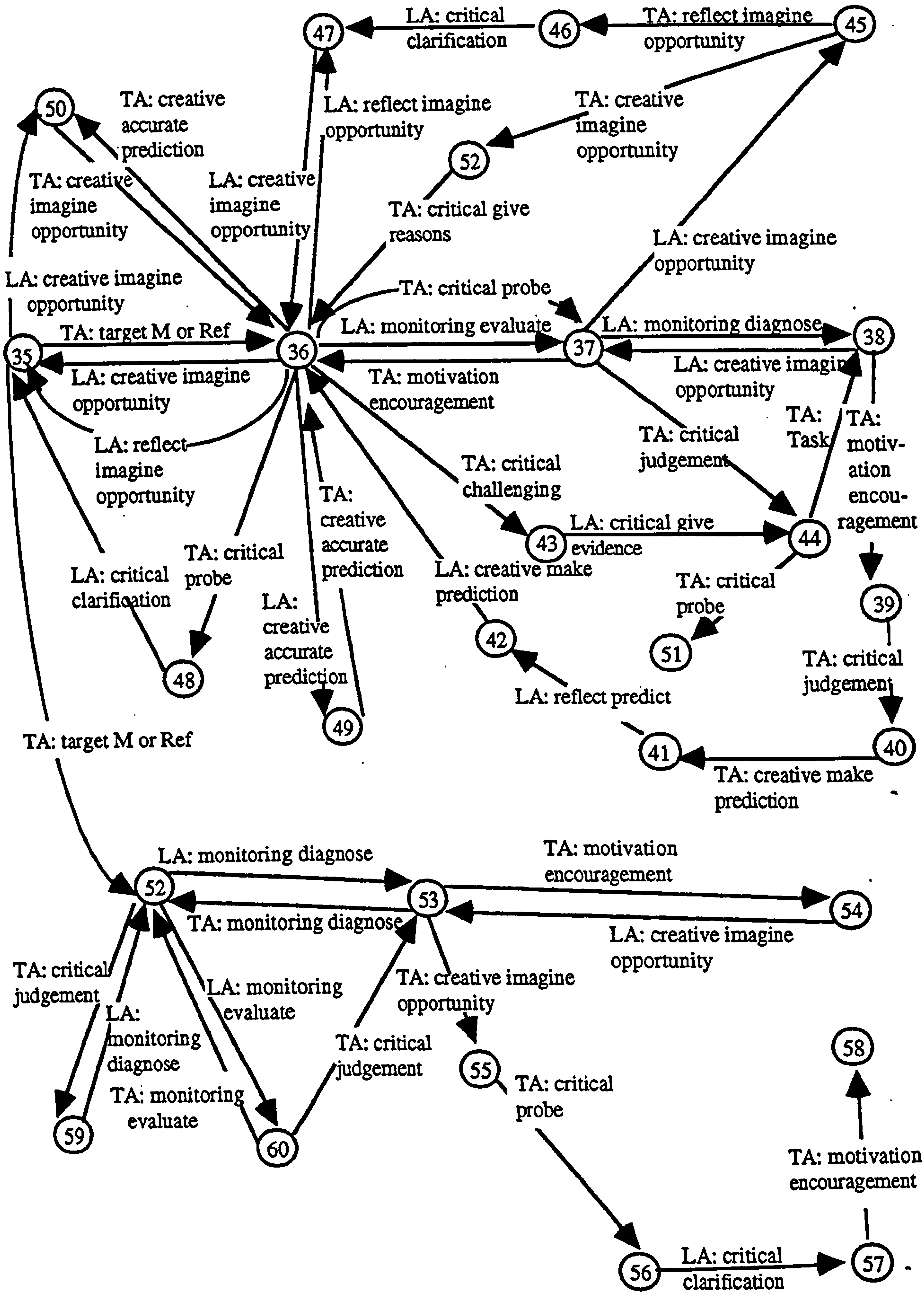

Figure A8.6. Stage 5 network for iterative use of target M or Ref.

A point worth noting about Figure A8.6 is that the 4th session did not integrate too well with the network for sessions 1 to 3, and so is drawn separately at the bottom of the diagram using states 52 onwards.

2.6 Stage 6 - Return to Mentor probing

The network shown in Figure A8.7 covers all the goals observed in sessions 1, 2 and 4 for the sixth mentoring stage with the minor proviso that in session 1 two 'TA: motivation give encouragement' goals are missing in the interaction. Sessions 1 and 2 finish on state 73, session 3 did not have this stage, and session 4 ended on state 70. Note that the start state 61 is chosen for convenience, the previous stage has multiple end states).

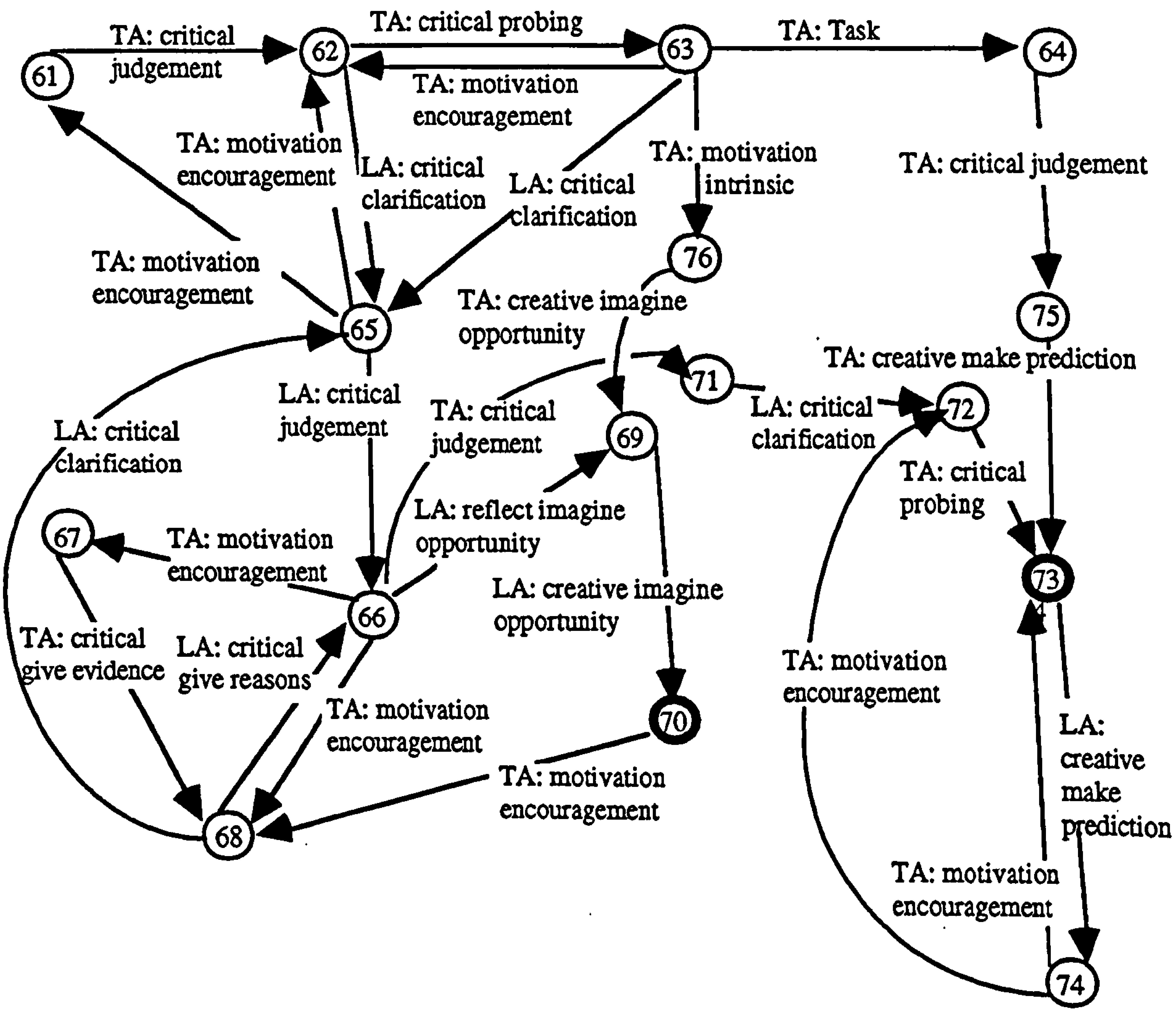

Figure A8.7. Stage 6 network for return to probing.

2.7 Stage 7 - End session.

Figure A8.8 shows the seventh and final mentoring stage for all sessions, which is basically a call to the task goal to end the session.

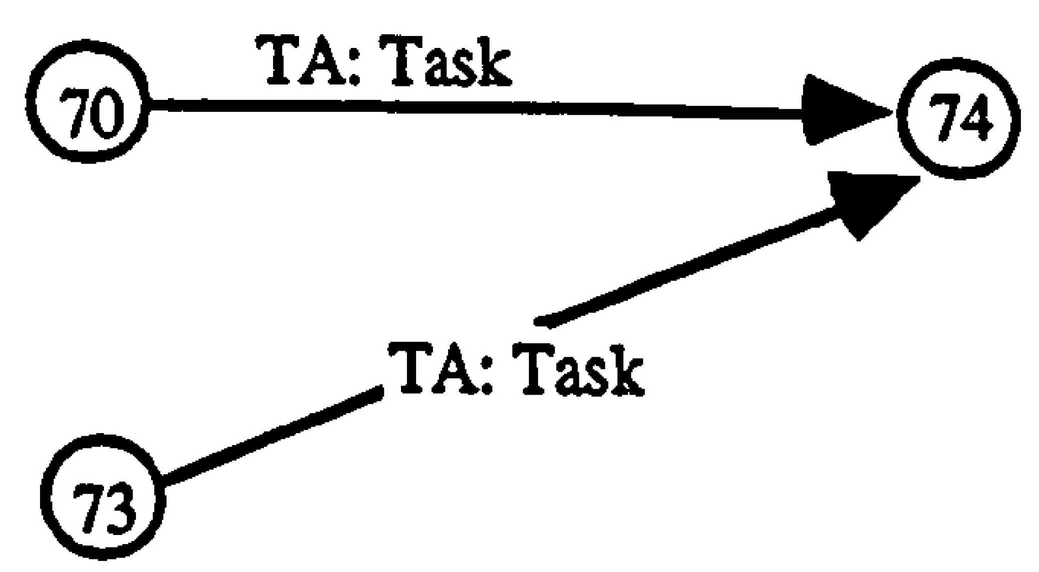

Figure A8.8. Stage 7 network for end of session.

Appendix 9. Extracts from the Code for MetaMuse

The following components of the agent architecture are detailed in the teaching agent code listing provided here:

1. Value System Machine
- example agent routines (adapted from Blandford's WOMBAT code)
- preference mechanisms (adapted from Blandford's WOMBAT code)
2. Action Selection Machine

Below we draw attention to aspects of the code that are of interest (the self-documentation explains the points that are of interest). Relevant aspects of these examples of the teaching agent code are explained in Section 6.3 of the thesis.

1. Value System Machine

1.1 example agent routine

```
;dialogue_tree_get returns the required information about a goal tree.
;It consists of sub-lists. When called in the appropriate manner
;one sub-list is returned. For every goal there is a list of sub-goals , and
;each of these sub-goals is represented in the 'relevant list except for the
;first (so that the ordering is defined).
;
;sub-list1: 'relevant says when it is relevant to address a sub-goal
;Each 'relevant sublist takes the form (sub-goal N (goalreached sub-goal M))
;Where sub-goal N can only be addressed (is 'relevant') when sub-goal M has
;been reached. These conditions are taken from the STN and provide the
;agent with expectations of the next goal that it would like to pursue.
;In cases where there are multiple goals in the goalreached list, sub-goal N
;is relevant when any of the goals has been reached.
;
(defun dialogue_tree_get (label)
;each sub-goal should have a relevant list (except the first: start_mentor) so that
;the ordering is defined.NOTE: should be all mentor goals, to be nice and clean, but
;using empirical data means that the node state is at a higher level than a turn
;sub-goal
;because it specifes the possible exit transitions (turn intermediate level sub-goals)
;for the current node.
 (cond ((equal label 'relevant)
     '((target_M_or_Ref_1 (goalreached monitoring_evaluate))
      (node_9 (goalreached monitoring_evaluate))
      (node_10 (goalreached monitoring_evaluate))
      (node_31 (goalreached monitoring_evaluate))
      (critical_probing_1 (goalreached target_M_or_Ref_1))
      (critical_probing_2 (goalreached target_M_or_Ref_1))
      (motivation_encouragement (goalreached target_M_or_Ref_1))
      (critical_challenging (goalreached target_M_or_Ref_1))
      (critical_clarification (goalreached critical_challenging))
      ))
; apt = achieve progress towards. Every apt goal should have its sub-goals defined.
; agent_wants uses this list to get list of wants for a goal.
; [if only two items in the list 2nd is an inout function; if >2 then it is a
; list of possible goals, then sub-goals is defined in 'subparts]
    ((equal label 'apt)
     '((start_mentor target_M_or_Ref_1)
      (node_6 target_M_or_Ref_1)
      (node_8 target_M_or_Ref_2)
      (node_9 critical_challenging_1 task_1)
      (node_10 target_M_or_Ref_2 critical_probing_1
          motivation_encouragement_1 critical_judgement_1 critical_probing_2)
      (node_31 critical_give_reasons_1 critical_clarification_1
```

```
        critical_probing_4 critical_probing_5 imagine_opportunity_1)
    (node_27 critical_probing_6 critical_judgement_2 motivation_encouragement_2)
    ))
;subparts is not used in MetaMuse as it doesn't seem to do what I want
;    ((equal label 'subparts)
;     '(node_10_start_mentor target_M_or_Ref_2 reflect_imagine_opportunity_1
;      monitoring_diagnose_1))
   ))
;
```

1.2 preference mechanisms

```
;++++++++++++++++++++++++++++++++++++++++++++++++++++
;preference mechanism:
;++++++++++++++++++++++++++++++++++++++++++++++++++++
;
;prefer selects between alternative sub-goals (wants) based on its value
;system. The values in WOMBAT were "totally engineered".
;However, in MetaMuse they are derived frm the empirical work. All that's encoded
;here is explicit values and weights (importance ratings).

;There are two lists; one is
;means-ends beliefs in the form ((act1 value1 cond1)(act2 value2 cond2)...)
;- i.e.act achieves progress towards value under condition, by act I mean turn sub-
goal!
;The second is simple values and weights (importance ratings)
;
;If there is only one possible sub-goal, prefer returns it. If there are more
;then it calls prefersub with three parameters:
;parameter1 - a list of means-ends beliefs relevant to the
; current decision [see me_get below]
;parameter2 - a list of weighted values [see wval_get below]
;parameter3 - list of current wants (i.e. sub-goals relevant to the current
;goal as specified
;by the relevant STN
;
;====================me_get============================
;me_get gets the means-ends beliefs relevant to the current decision. MetaMuse uses
;state_node instead of goal (which was used by WOMBAT) as a parameter to reflect
;my approach.
;
;Example for node_10 the mentor exit transitions are: target_M_or_Ref_2,
;critical_probing_1,motivation_encouragement_1, and critical_judgement_1
;if we take target_M_or_Ref_2, below. It is made up of:
;diagnose_follows_evaluate is in wval_get and
;has a weight of 50 from the mentoring script.
;This was calculated from empirical data (see method 2 below).
;
;no_diagnosis is a function that returns t if there is no learner diagnosis in
;*believes* (i.e. the learner has not input a diagnosis, they may have selected a
;different respond menu option.If this function evaluates to t then the weighting of
;50 goes into the final reckoning, done by findbest, of all weights for this node.
;As this example illustrates, the weight only come into play in the preference
;mechanism if the learner has not made a diagnosis.
;
;critical_probing_2 [not shown here] is there to make interaction more adaptive.
;If learner evaluated
;the pharse as not as expected or maybe as expected then probing takes priority
;
(defun me_get (state_node *agent_state*)
 (cond ((null state_node) nil)
    ((equal state_node 'node_10)
     `((target_M_or_Ref_2 (diagnose_follows_evaluate (no_diagnosis ,*believes* )))
      (critical_probing_1 (probing_follows_evaluate (wasit_what_expected ,*believes*

                  )))
      (motivation_encouragement_1 (ass_conf_follows_evaluate
                  (return_t ,*believes* )))
      (critical_judgement_1 (crit_judgement__follows_evaluate
               (return_t ,*believes* )))
```

```
    (critical_probing_2 (probing_as_repair (wasit_what_expected ,*believes* )))
    )
   )
  ((equal state_node 'node_9)
   `((critical_challenging_1 (learner_maybe_inarut
              (refused_advise ,*believes* )))
    (task_1 (learner_notinput_list
              (notinput_list ,*believes*)))
    )
   )
  ((equal state_node 'node_31)
   ;look down column in spreadsheet for incoming (to node 31) learner interventions
   ;i.e. monitoring eval. and critical clarification, and pick highest scoring
   ;responses from mentor. Thus for node 31 we get:
   ;for monitoring evaluate - critical_give_reasons = 0, critical_clarification
    ;= 1, critical_probing = 3, imagine_opportunity = 2
       ;for critical clarification- critical_give_reasons = 1,
critical_clarification
       ;= 0, critical_probing = 5, imagine_opportunity = 0. Probing scores highest
       ;for both. Routines for critical_give_reasons_1 and imagine_opportunity_1 are
       ;included for completeness (althogh they will only be called if both
       ;recent_eval and recent_clarific return nil.
       `((critical_give_reasons_1 (give_reasons_follows_clarification (return_t

            ,*believes* )))
          (critical_clarification_1 (clarification_follows_evaluate (return_t

                  ,*believes* )))
          (critical_probing_4 (probing_follows_evaluate (recent_eval ,*believes* )))
          (critical_probing_5 (probing_follows_clarification (recent_clarific

                  ,*believes* )))
          (imagine_opportunity_1 (imagine_opportunity_follows_evaluate (return_t

             ,*believes* )))
          )
        )
       ;At node 27 we get:
       ;for imagine opportunity - motivation encouragement = 7, critical judgement
       ;= 3,critical probing = 5
       ((equal state_node 'node_27)
        `((critical_probing_6 (probing_follows_imagine_opportunity (return_t
,*believes*
                         )))
          (critical_judgement_2 (judgement_follows_imagine_opportunity (return_t

            ,*believes* )))
          (motivation_encouragement_2 (encouragement_follows_imagine_opportunity

      (return_t ,*believes* )))
          )
        )
       ))
;
;
;wval_get gets the weights and values relevant to the current decision.
;At the moment it just pulls in the whole data structure!!
;Weights are calculated in three ways:
;
;Method 1: Analysis 3 intervention-response counts (the spreadsheet) are used
;to derive ferquency counts of links in the script.
;For example, monitoring evaluate to motivation encouragement
;(specifically assertion confirmation, which includes all motivation encouragement
;plus dialogue management scores).
; Analysis 3 spreadsheet shows that the most
;common mentor response to a learner monitor evaluate  was assertion confirmation
;(score = 20). Therefore, the likelihood of this link occurring =
;(20*100) ÷ 59 = 33.8%. Where 59 is the total number of different mentor responses
;to the learner intervention monitoring evaluate (sum of column B in spreadsheet
;shown in Appendix 5 of thesis).
;
;Method 2: uses analysis 2 findings to generate expectations for a particular
```

```
;sequence. For example:
;  for monitoring-evaluate to monitoring-diagnose (from analysis 2), it was found that
;  6 out of the 12 occurrences of 'monitoring diagnose' were preceded by
;  'monitoring evaluate' by the student. Therefore, the likelihood of this
;  link occurring = (6*100) + 12 = 50%
;
;Method 3: weights are not empirically derived (I made them up!).
;Poss Method 4 - in analysis 1 the total number of teacher goal interventions was
;identified as 197. The total number of learner goal interventions was 210.
;These totals are sometimes used to calculate the likelihood (i.e. frequency) of a
goal
;occurring in the mentoring script and in the weights below.
;
(defun wval_get nil
  '((diagnose_follows_evaluate 50)                    ;method 2 - (6*100) + 12  = 50
    (probing_follows_evaluate 5)                      ;method 1 - (3*100) + 59  =  5
    (probing_as_repair 40)                            ;method 3
    (ass_conf_follows_evaluate 33)                    ;method 1 - (20*100)  + 59 = 33
    (crit_judgement__follows_evaluate 10)             ;method 1 - (6*100)   + 59 = 10
    (learner_maybe_inarut 20)                         ;method 3
    (learner_notinput_list 30)                        ;method 3
    (probing_follows_clarification 10)                ;method 1 - (5*100) + 46  =  10
    (give_reasons_follows_clarification 2)            ;method 1 - (1*100) + 46  =   2
    (clarification_follows_evaluate 1)                ;method 1 - (1*100) + 59  =   1
    (imagine_opportunity_follows_evaluate 3)          ;method 1 - (2*100) + 59  =   3
    (encouragement_follows_imagine_opportunity 13) ;method 1 - (7*100) + 52  = 13
    (judgement_follows_imagine_opportunity 5)         ;method 1 - (3*100) + 52  =  5
    (probing_follows_imagine_opportunity 9)           ;method 1 - (5*100) + 52  =  9
    ))
;
;====relevance functions==============================
;These are the relevance functions that MetaMuse needs to check states and variables.
;used above in the preference mechanism

;*believes* can look like this:
; ((evaluation (i am not certain if the phrase was what i expected))
; (diagnosis) (imagined_opportunity))
;
;dummy routine that returns true so that the weight will be included in
;findbest
(defun return_t (*believes*)
  t)
;
;no_diagnosis returns t if the learner has not made a diagnosis
;or nil otherwise
(defun no_diagnosis (*believes*)
  (cond ((null (list_extract '(diagnosis) *believes*)) t)
        (t nil)))

;refused_advise returns t if the learner has ignored advice three times to
;make a diagnosis or nil otherwise
(defun refused_advise (*believes*)
  (cond ((equal *refuse_advice* 3) t)
        (t nil)))

;checks to see if learner is uncertain about their own evaluation (was it what
;they expected?), if this is the case then return t, also returns t if *refuse_advice*
; > 0, else returns nil
(defun wasit_what_expected (*believes*)
  (cond ((equal (car (list_extract '(evaluation) *believes*))
                "The phrase was not as expected") t)
        ((equal (car (list_extract '(evaluation) *believes*))
                "I am not certain if the phrase was what I expected") t)
        ((> *refuse_advice* 0) t)
        (t nil)))

;recent_eval returns t if learner has recently made an evaluation, at node 26.
;Earlier, critical_probing_2 (in action machine but related to node 10) saves
;evaluation into evaluation_initial in an attempt to avoid looping. Or node_26_menu
;does the same.
(defun recent_eval (*believes*)
  (not (null (list_extract '(evaluation) *believes*))))
```

```
;notinput_list returns t if the learner's list 'evaluation' is not empty or
;nil otherwise
(defun notinput_list (*believes*)
  (cond ((null *list*) t)
        (t nil)))

;recent_clarific returns t if the learner's list 'clarification' is not empty
;or nil otherwise
(defun recent_clarific (*believes*)
  (not (null (list_extract '(clarification) *believes*))))
;==========================================================
```

2. Action Selection Machine

CP_CA_decide below shows how adaptivity at the local level is provided by MetaMuse (sort of local planning). It reaches a decision about what act to perform for critical_probing on the basis of the contents of *probing* and *analysis_type*.

```
;************************************************************
;                       ACTION SELECTION MACHINE
;************************************************************
;************************************************************
;
;Output routines for MetaMuse, plus some decisions made about what output suits
;current circumstances.

:
:

;======== work done on CAs related to probing ===============
;used if probing_follows_clarification causes its selection by preference
;mechanism at node 31
(defun critical_probing_5 (*agent_state*)
  (window-close *sop*)
  (setf *probing_count* (+ *probing_count* 1))
  (setf *current_node* '26)
  (CP_CA_decide *agent_state*)
;  (null_node *sentence*) *agent_state*)
  ;now set up *sentence* ready for move back to node 26 so that the learner
  ;profile makes sense.
  (setf *sentence* 'nil)
  (setf *sentence* (list "
Learner answer to probing about " *probing*))
  (node_26_menu *agent_state*)
   *agent_state*)

;*probing* contains details of last probing used (to avoid duplication
;of effort). Types are: leaps_segment, playing_on_instrument, how_many_phrases
;
;*analysis_type* to contain either:
;list_empty octave_leaps decending_trajectory ascending_trajectory
;large_leap repeated_transposition boring
;
;CP_CA_decide reaches a decision about what act to perform for critical_probing
;on the basis of the contents of *probing* and *analysis_type*
(defun CP_CA_decide (*agent_state*)
  (setf *current_node* '26)
  (cond ((not (equal *probing* 'playing_on_instrument))
         (playing_on_instrument_CA *believes*))
        ((equal *analysis_type* 'large_leap)
         (large_leap_CA *believes*))
         (t (how_many_phrases_CA *believes*))) *agent_state*)


(defun playing_on_instrument_CA (*believes*)
  (window-close *sop*)
  (setf *probing* 'playing_on_instrument)
  (setf *sentence* 'nil)
```

```
  (setf *sentence* (list "You evaluated your phrase (using the pop-up menu and
data entry) as:
"(list_extract '(evaluation) *believes*) " "
                          (list_extract '(evaluation_initial) *believes*) "
(Please ignore any nils above)
Try imagining you are playing the phrase on an instrument. How would you articulate
it? Please explain your creative idea, i.e. any changes you would like to
make to the phrase. Select the Respond menu."))
  (put_output_sentence *sentence*)
  (setf *context_probe* "
Learner response to MetaMuse's probing about imagining you are playing the
phrase on an instrument:
") *agent_state*)

(defun large_leap_CA (*believes*)
  (window-close *sop*)
  (setf *probing* 'leaps_segment)
  (setf *sentence* 'nil)
  (setf *sentence* (list "Let me try and understand what you intended.
This very large leap" *leaps*  " Does it segment the music?
Use the respond menu to answer the question."))
  (put_output_sentence *sentence*)
  (setf *context_probe* "
Learner response to MetaMuse's probing about Does the large leap segment
the music?:
") *agent_state*)

(defun how_many_phrases_CA (*believes*)
  (window-close *sop*)
  (setf *probing* 'how_many_phrases)
  (setf *sentence* 'nil)
  (setf *sentence* (list "Let me try and understand what you intended.
If you had to put in phrasing marks, where would you put them?
By using the Windows menu to select the Midi-file palyer palette (which will be
called either 'Click to play' or 'Again, click to play'), try playing the phrase
through again and then consider the above question. Then use the respond menu to
answer the question."))
  (put_output_sentence *sentence*)
  (setf *context_probe* "
Learner response to MetaMuse's probing about If you had to put in phrasing
marks, where would you put them?:
") *agent_state*)
```

Appendix 10: Formative Evaluation of Teaching Agent (MetaMuse)

1. Notes given to the evaluation participants

(Note: participant 1 and 2 were given the first and second sections in advance of the evaluation sessions. Participants 3-5 received something similar to the first two sections below in advance of their sessions.)

MetaMuse Formative Co-Evaluation Notes by John Cook

Background

Thank you for agreeing to take part in this evaluation. First, please read through these notes and ask for clarification from your co-evaluator (John Cook) at any point.

The role of a formative evaluation is to use a study to drive the design and specification of a system by testing intermediary versions which incorporate features of the design. Co-evaluation is an approach that places emphasis on a user working through a task and answering such questions as: What will the system do if? What has the system done? Why has it done that? Other approaches to evaluation tend to regard users as experimental subjects.

The system you have agreed to co-evaluate is called MetaMuse. It has been constructed as part of my PhD studies at The Open University. MetaMuse is a pre-prototype teaching assistant that is based on empirical data (i.e. studies of how a human teaches). A pre-prototype is limited in what it can do because it only incorporates one or two features of a full system. What MetaMuse can do is structure the interactions with a learner in a way that will, hopefully, promote reflection. A session with MetaMuse results in a 'Learner Profile': a log of the student's answers to questions and reflections. The Learner Profile is intended to be used by a student as the basis for more self-reflection, or for further discussion with a teacher or with another student.

MetaMuse can not understand natural language. The system is not able to engage in dialogue about the 'free text' inputs by the learner. As a result the system sometimes lets the user input some thoughts on what they are doing, stores these explanations and reflections in the learner profile, and then moves on to the next part of the session. Interactions with MetaMuse thus typically takes the form of structured questioning by the system. However, within certain limitations the system is able to comment on a musical phrase input by the learner.

MetaMuse can only deal with a small task revolving around the chromatic transposition of a four note phrase. As was pointed out above, what MetaMuse tries to do is to get the learner to reflect about what they are doing. Some research has shown that by getting learners to accurately predict or explain what they are about to do, and what they have just done, we can promote effective learning (see next section).

The role of this formative co-evaluation is that of a pilot study, i.e. to test the features that have been implemented. The *aim* of the evaluation, therefore, is to get initial feedback from music teachers and educational technology researchers on two questions: (i) does MetaMuse promote creative reflection?, and (ii) what potential does MetaMuse have for assisting in undergraduate composition classes? The findings of this initial co-evaluation will be used to inform the construction a full prototype, which will then be evaluated with students.

When you are using the system, please feel free to ask any questions about MetaMuse as you progress. However, please note that John Cook is here in the role of a co-evaluator (requiring that you as the other co-evaluator should, as far as possible, discover the strengths and limitations of the system for yourself). After you have used the system, you will then be asked to fill in a small questionnaire. The whole session should only take between 60 and 80 minutes.

Why learn how to predict?

Making a prediction is a learning strategy. The basic idea is that musical thinking can be improved by talking.

MetaMuse uses a mentoring approach to encourage creative reflection in a learner. Creative reflection is defined as the ability of a learner to imagine musical opportunities in novel situations and to then make accurate predictions (verbally) about these opportunities. To succeed at creative reflection there should be a correspondence between what a learner predicts will happen and what actually happens. An example would be a learner first writing a phrase using musical notation, then predicting verbally how that phrase will sound, playing the phrase back on a piano and finally evaluating if the prediction was accurate or not.

Since the mid-1980s, there has been a movement away from knowledge supplied by the teacher and towards talking, reflecting and explaining as ways to learn. An example of this change in focus is provided by the self-explanation work, an approach to talking science rather than a hearing science. Generating explanations to oneself (self-explanations) facilitates the integration of new information into existing knowledge.

If we examine one aspect of self-explanation we find that in music, meaning, for example, has to be built up successively. Centuries of composers' hand-written sketches (i.e. self-explanation) show how composers accrue representations of musical meaning using strategies that act on musical ideas in a cumulative and evolving fashion, play with ambiguity, whilst keeping resolutions on decision-making on hold for as long as possible. This is elegantly demonstrated in the sketchbooks of Beethoven and Stravinsky.

How does transposition work in MetaMuse?

The technique used in MetaMuse for transposing a pre-set pattern (C C# F# G is initially given) is simply to use a transposition number (which represent semi-tone steps, i.e. chromatic transposition). By creating a list of transposition numbers in relation to a base position (value 0) a musical phrase or section may be produced.

- Zero in the list will simply give a repetition of the pre-set pattern (i.e. C C# F# G),
- -7 transposes the pre-set pattern down a fifth (i.e. it produces F F# B C),
- -12 plays the whole pattern an octave lower, and so on.
- Playing the list '0 -7' would produce the phrase C C# F# G F F# B C.

A 'MIDI-file player palette' (see Figure 1) can be generated for a list of transpositions. Playback is always with a regular rhythm.

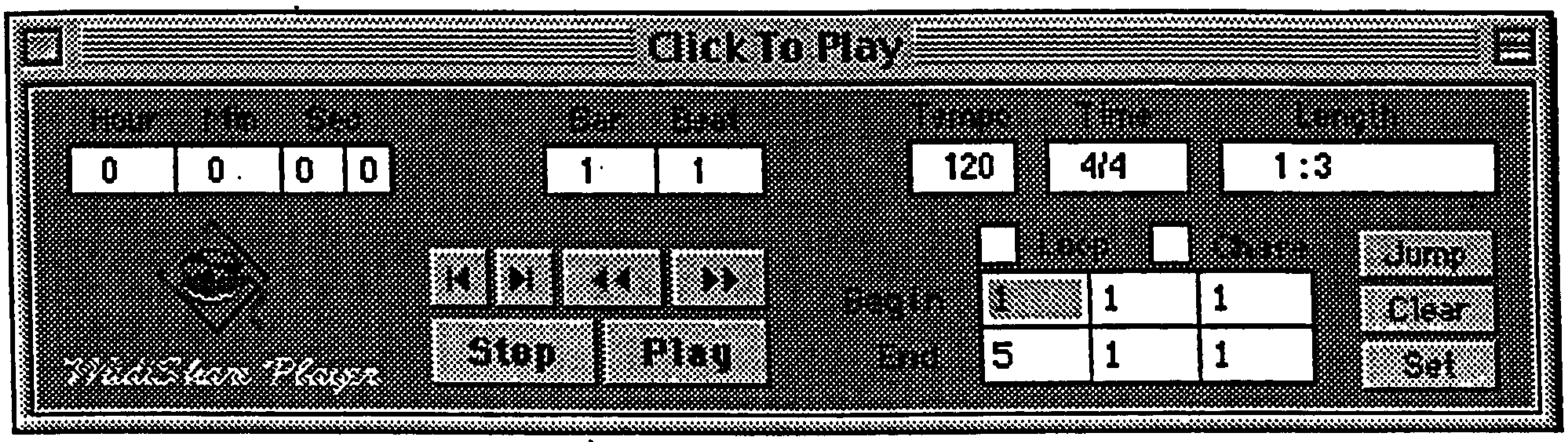

Figure 1: Midi-file player palette

The task using MetaMuse

The compositional task that I would like you to attempt, using MetaMuse, is to create a phrase by the repeated chromatic transposition of an initial four note phrase (C C# F# G). When using MetaMuse to compose a phrase you will be asked to limit the approach you use, when transposing the phrase, to repetition, contrast and trajectory (MetaMuse will give guidance on this). The reason for this is that MetaMuse knows more about how to interact than it does about music (later versions will improve on this lack of musical knowledge).

Because MetaMuse doesn't have much in the way of musical knowledge, it is necessary for you to limit the types of phrase that you enter. MetaMuse can recognise the following, so please limit yourself to variations on one of these approaches when composing a phrase (this is after all only a first pre-prototype!):

- octave leaps, e.g. 12 24 -48 0 12 -36
- descending trajectory, e.g. 33 12 0 -2 -12 -20
- ascending trajectory, e.g. -20 -12 2 0 12 33
- large leaps, e.g. 0 1 2 40 2 1 0 3 2 1
- repeated transposition, e.g. 2 2 2 2 2 2 2 2 2 2 2 2 2 2
- small phrase, e.g. 0 1

Note the space in between each transposition value. Please do not mix the above approaches up in one phrase. Feel free to ask any questions or make comments during the interaction with MetaMuse. In particular I would like you consider the following questions after each of the outputs produced by MetaMuse (it has its own special output window):

- is the utterance sensible?
- does the interaction cause you to reflect?

Please remember to speak out loud, as much as you feel able to, whilst you consider the above questions.

Next step: Please tell the evaluator that you are ready for a quick demonstration of MetaMuse.

2. Questionnaire responses

2.1 Profile of the participants
(Response to first question on the questionnaire.)

Participant 1

Date and location of co-evaluation: 21 May 1998, London
Job title: Lecturer in Computing (in a 'new' North London University)
Professional qualifications: BA, MSc, PhD AI/Music/(ed.)
Specialism

The type of music teaching that you do:
Try to develop AI based software to support novice melody/harmony composers.

Experience with educational technology:
Lots of software evaluation and development.

Participant 2
Date and location of co-evaluation: 14 June, 1998, Wakefield, Yorkshire, UK
Job title: Composer, music lecturer, educator
Professional qualifications: BMus, LEAM (Performance and teaching)
Specialism

The type of music teaching that you do:
Composition on a Contemporary Music Studies BA (Hons). Analysis, orchestration, acoustics, music IT on a Performance Studies BA Hons.

Experience with educational technology:
Extensive - since 1985 with MIDI systems for music.

Participant 3
Date and location of co-evaluation: 15 June, 1998; a university college in the NE of England
Job title: Lecturer in Popular Music Technology and Theatre Technology
Professional qualifications: BEng Music Technology (York)
Specialism

The type of music teaching that you do:
Music Technology - Studio recording, sampling, video, acoustics, live sound engineering and sequencing.
Theatre Technology - Lighting design and sound design.

Experience with educational technology:
See above

Participant 4
Date and location of co-evaluation: 15 June, 1998; a university college in the NE of England
Job title: Programme Coordinator/Contemporary Music
Professional qualifications: BSc, MSc and PhD
Specialism

The type of music teaching that you do:
Contemporary music, history and performance.

Experience with educational technology:
Very little.

Participant 5
Date and location of co-evaluation: 15 June, 1998; a university college in the NE of England
Job title: Composer/Teacher (former Head of Department of Music)
Professional qualifications: MMus
Specialism

The type of music teaching that you do:
Higher Education.

Experience with educational technology:
Limited.

2.2 Summary of response to other questions
(i.e. responses to questions 2-6)

Question 2. Please tick ONE box on the five point scale below that best describes how INTERESTING you found MetaMuse. On a scale of 1 (not at all interesting) to 5 (very interesting) response scores were:
1 = 0; 2 = 0; 3 = 1; 4 = 1; 5 = 3

Comments made:
Participant 1: Interesting to find it so engaging, gives just numbers and listening.
Participant 2: MetaMuse highlights the essential composition skill/requirement of MEMORY. It encourages reflection about both macro and micro aspects of a short composition. The language and display of text needs a radical rethink! A session with students on the language used would be essential - and a good thing to do anyway as this kind of formal language use is not (but should be) encouraged.
Participant 3: Needs a musician friendly front end - notes not numbers - click on a topic for more information.
Participant 4: Strikes me as a potentially useful tool for young composers trying to work in a medium not necessarily based in pop, but which nonetheless not electroacoustic.
Participant 5: Compositional value in teaching very useful. Patterns are quite limiting - which make a good test of both 'learning' and 'ingenuity'. It would be further use in teaching to [be able to] play around with the pattern (invert, retrograde) and with tempo.

Question 3. Please tick ONE box on the five point scale below that best describes how USEFUL you found the way that MetaMuse promotes creative reflection about a musical phrase. On a scale of 1 (not at all useful) to 5 (very useful) response scores were:
1 = 0; 2 = 0; 3 = 1; 4 = 2; 5 = 2

Comments made:
Participant 1: [I] wouldn't have thought of imagining performance or phrasing without prompting. Multiple audio playback is essential.
Participant 2: [No comments made.]
Participant 3: More advice about what to try - ability to continually adapt the phrase at each stage.
Participant 4: It would probably be more helpful if it were able to pick up on key words in the responses and therefore not ask questions which have already been answered. However, the process of evaluation is useful, although I'd be interested to see how it coped with larger structures.
Participant 5: At the initial stage. Needs to explore further how small components can contribute to a larger frame (structure : form).

Question 4. Please tick ONE box on the five point scale below that represents your assessment of the POTENTIAL that MetaMuse has for assisting in undergraduate composition classes. On a scale of 1 (no potential at all) to 5 (a lot of potential) response scores were:
1 = 0; 2 = 1; 3 = 0; 4 = 2; 5 = 2

Comments made:
Participant 1: Not sure how advanced undergraduates go. Would need to allow combinations of motive transformations I think, to be more widely used. Why not younger School children? 'O' and 'A' level!
Participant 2: Focusing on such limited material and a single musical parameter of transformation provides a starting point for many other related exercises or studies. It encourages you to think fast and maintain a creative and critical continuation that is actually very similar to what you experience when composing 'for real'.
Participant 3: If it could work with more aspects of composition - is it possible to get it to undergraduate level? Better at primary (secondary level)?
Participant 4: Certainly at level one - it encourages one to think in very localised terms and hence it provides a means of learning to walk before running. With more flexibility

in the types of structures/phrases it can cope with, the benefit would increase.
Participant 5: As above. The colour of different instrumentation would be useful - patterns differ with their instrument!

Question 5. Please tick ONE box on the five point scale below that best describes your assessment of how USEFUL you found the guidance provided by MetaMuse. On a scale of 1 (not at all useful) to 5 (very useful) response scores were:
1 = 0; 2 = 1; 3 = 3; 4 = 1; 5 = 0

Comments made:
Participant 1: To start with I was "polite" and just did what asked. Later [I] was reflecting a lot and had to look for places to write it down!
Participant 2: As it stands this system's guidance messages and information would best be read by a pair of students who could together deliberate on the text.
Participant 3: Sometimes ambiguous - particularly when answering questions.
Participant 4: [see response to] question 3.
Participant 5: Perhaps a greater range of detailed questioning.

Question 6. Please tick ONE box on the five point scale below that best describes your assessment of how USEFUL you think the learning approach used by MetaMuse is for musical composition education (i.e. learning how to make predictions and reflecting on what actually happened). On a scale of 1 (not at all useful) to 5 (very useful) response scores were:
1 = 0; 2 = 0; 3 = 1; 4 = 0; 5 = 4

Comments made:
Participant 1: Was <u>very</u> informative to make and evaluate predictions. I didn't expect to be <u>wrong</u>. Perhaps guide learner to be <u>more</u> detailed (i.e. committed to their predictions ...). Without <u>guide</u> to ascend and use contrast, etc., I wouldn't have known where to go.
Participant 2: Except on a one to one basis, I cannot imagine any other way of achieving this experience. This does test and help develop memory and critical thinking in a relatively non-threatening manner.
Participant 3: Most undergraduates would be at too high a level. Better on Primary/Secondary.
Participant 4: Overall, I think this could be very useful in terms of a learning tool in encouraging students to think about both local events and (potentially) larger scale events; and the process of constructing events to create cohesive work.
Participant 5: Excellent introduction to <u>awareness</u> of sound.

Other notes.
Because participant 1 and 2 were well known to the author of this thesis, at the end of filling in the questionnaire both were asked: "Are you being an objective researcher?". Both participants replied "yes" (participant 1) and "yes, try to be" (participant 2). Furthermore, neither participant 1 or 2 had seen the teaching agent before the co-evaluation session.

<u>3. Changes made to MetaMuse following session with Participant 1</u>

1. Unclear wording on initial information screen, produced when button 1 and 2 used, therefore changed.

2. First MetaMuse output not precise in reference to menu option, therefore changed from:
"OK, you think it worked. Try choosing **diagnose** from the respond menu and say why you think it worked."

to:
"OK, you think it worked. Try choosing '**diagnose the phrase**' from the respond menu and say why you think it worked."

3. Wording of the second option of the respond menu for node 26 caused confusion (it wasn't obvious that this should have been chosen in the current context). Therefore changed from:
"Provide clarification in response to the question"

to
"Answer the question"

4. Also, the following new wording given to a message:

"Try imagining you are playing the phrase on an instrument. How would you articulate the phrase?.
Please 'explain your creative idea' (i.e. how would you physically play the phrase on an instrument?)
by selecting an option from the Respond menu."

also, related (to the above) input box prompt changed from: "Assert your imagined opportunity below." to "Assert your creative idea below."

5. Also, a small bug in a function that was supposed to test for lists of <4 transposition values was spotted and fixed (the buggy version actually tested for <3).

6. The wording of a node 11 Respond option "Reflect for a while (on your idea)." caused confusion and was thus changed to "Pause for a while and reflect about your idea."

GOOD POINT RAISED (second side tape, near front)
I described that options were in Respond menu if they were found in empirical data (STN). Participant 1 said, that's interesting, so you might be encouraging me to do something by a student who didn't do particularly well. I said MetaMuse only makes recommendation if got evidence that it is good to do it ... e.g. diagnose. This point is an interesting one.